Ancient Astronomy:

An Encyclopedia o
Cosmologies and Myth

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Introduction

The Wonder of the Skies

The sight of a truly dark night sky is simply breathtaking. In the modern world it is denied to all but those who still live, or might occasionally venture, well beyond the glare of city lights and the effects of atmospheric pollution. For people in the past, though, the panoply of thousands of stars was a familiar sight. Some twinkled particularly brightly; others hovered on the borderline of visibility. A few were tinted orange or blue. They formed distinct patterns that moved around but never changed. The Milky Way was a familiar sight to all, snaking across the heavens with its light and dark patches forming recognizable shapes. The sky also contained numerous isolated faint and fuzzy objects (nebulae), fixed among the stars, as well as bright wandering stars (planets), and of course the moon, dominating the night sky, lighting the way by night, and rendering many of its fainter companions temporarily invisible. Added to all this was the occasional appearance of something rare or totally unexpected: a shower of meteors (shooting stars), a lunar eclipse, an aurora (at high latitudes), or—more seldom still—a comet (often perceived as a tailed or plumed star) or a new star (nova).

The exact appearance of the heavenly vault differed from place to place and time to time. Whether it was visible on a particular night was dependent, of course, upon local weather conditions. However, the visual impact of the sky on a clear night was always stunning, and even in the cloudiest and wettest of places there were a good many clear periods. As a result, human communities the world over, and for many thousands of years, have recognized familiar patterns and cycles of change in the skies, as well as unexpected sights and events, and struggled to make sense of them. The inhabitants of the night sky—whether perceived as animals, fantastical creatures, legendary characters, ancestors, or other entities—were ever present. The cycles of their appearance and disappearance provided the basis for, and reinforced, countless creation stories and cultural myths.

The lack of opportunity to experience the true night sky is, for a great many people in the modern Western world, something beyond their control. The same cannot be said, though, of the daytime sky, and yet few people pay much attention to it beyond worrying about the weather. Only a meager proportion—and this does not just apply to city-dwellers—could, for example, orient themselves from the time of day and the position of the sun, or could accurately describe the way in which the sun's daily arc through the sky changes with the seasons.

As a result, it can be difficult for us to imagine just how great an impact the sky, whether by night or day, had upon human cultures in the past. Yet we need look no further than the many indigenous peoples today for whom the sky continues to be of immense importance. In addition to this, certain world religions such as Islam continue to tie daily and annual observances very explicitly to the appearance of the sun and moon (see ISLAMIC ASTRONOMY). And one only has to talk to some of the older people living in rural areas, even in the world's most densely populated and developed nations, to discover that an immense amount of practical, everyday sky knowledge was possessed even within living memory. Who, sky watchers of the past might wonder, could fail to notice the regular cycle of lunar phases keeping time with the human menstrual cycle? Who could fail to recognize the changing path taken by the sun through the sky, higher in summer and lower in winter? Who, even in an unfamiliar place, could fail to be able to tell directions and hence find their way about by night or day using the sun or stars?

Perceptions of the Skies in the Past

ARCHAEOASTRONOMY can be defined as the study of beliefs and practices concerning the sky in the past, especially in prehistory, and the uses to which people's knowledge of the skies were put. It has been recognized in recent years as a legitimate and worthwhile academic pursuit, but it also strikes a popular chord, bringing together two of the most attractive sciences, archaeology and astronomy. It combines the excitement of the cosmos with the romance of the past. Books making spectacular claims about ancient astronomical knowledge often find themselves on bestseller lists. But why should studying people's perceptions of the skies in history, let alone in prehistory, be of particular interest or importance to scholars, not to mention anyone else, in the twenty-first century?

One reason is that archaeoastronomy gives us important insights into how people in the past made sense of the world within which they dwelt. People's lives were governed by observations of objects and events in the world around them. On one level, it is obvious that human communities needed to keep track of various seasonal markers in order to control and maintain their food supply through the year. This would be true whether they subsisted by harvesting plants, fruits, and tubers, by fishing, by hunting, by herding animals or by growing crops, or (most commonly) by a combination of these. CALENDARS, however rudimentary, were necessary for survival in all types of human society: for the smallest bands of hunter-gatherers; for farming villages controlled by local chiefs; and for complex urban societies seeking to support the higher social echelons of elite specialists, craftsmen, priests, and kings.

But humans share a deeper need to understand the world that they inhabit. This does not necessarily mean seeing humankind (or the human mind) as existing within the "objective reality" of the natural environment, as is the modern scientific view, but more generally perceiving the cosmos as a conceptual whole with oneself and one's own community embedded within it. In such a view of the world, the human body, or the dwelling house, or the sacred temple, is often seen as a microcosm reflecting and reinforcing the nature and structure of the cosmos as a whole. Such a worldview makes people strive to be at one with the cosmos of which they are a part and achieve a harmony of existence that enables individuals and whole communities to survive and flourish. This harmony is sustained by continually observing what is happening in the world and keeping one's own actions in tune.

The sky was an integral and prominent part of the perceived cosmos. Its familiar sights and unceasing cycles were part of the fabric of life. Its rhythms were correlated with the time of day and with the seasons. In fact, although we know these cycles to be unfailingly regular and reliable, to past peoples they may not have appeared any more so than a host of other seasonal indicators in the world around them. The important point for us is that, unlike the rest of their perceived world, the sky is a part that we can visualize directly. Landscapes change: patterns of settlement and land use alter, people move around, plants constantly grow and die. We only have indirect knowledge of the appearance of past landscapes. But thanks to modern astronomy, we can reconstruct mathematically the actual appearance of the sky (or, at least, the regular aspects of it—that is, the appearance of the sun, moon, planets, and stars) at any place on earth at any time in the past and visualize it on a computer display or in a planetarium. This gives us a "direct view" of a prominent part of the world that was perceived by peoples in the past.

By studying knowledge passed down orally through myth and story, as well as a variety of other types of evidence available to the historian and the archaeologist, we can begin to appreciate the many different ways in which human societies came to understand what they saw in the skies, and how they came to "use" that knowledge for cultural ends. The sky could, for instance, affirm the POWER of cultural elites, as in the case of the Inca rulers, whose right to rule stemmed from their avowed relationship to the sun god himself (see *CEQUE* SYSTEM; CUSCO SUN PILLARS). Then again, it could reinforce the status of a shaman or priest who, by performing the appropriate rites at the appropriate times, could be seen as able to affect what happened in the sky—for example by reversing the direction of the sun at the winter solstice and preventing the days from getting ever shorter and colder. Likewise, people tend to lay out buildings in tune with the cosmos, in other words, reflecting perceived links with the wider world (see, for example, NAVAJO HOGAN; PAWNEE EARTH LODGE). Where these links relate to the sky—for instance, to the rising or setting position of the sun, moon, or stars—then we have particular hope of recognizing them, since we know where these celestial bodies appeared in the past (see HOW THE SKY HAS CHANGED OVER THE CENTURIES). By studying architectural alignments upon sky phenomena, we can obtain valuable insights into the worldviews that engendered them.

There is no reason investigations of people's perceptions of the skies should be limited to past societies, and a field known as *ETHNOASTRONOMY* has emerged in recent years alongside archaeoastronomy, concerned with studies of beliefs and practices relating to the sky among modern indigenous peoples. Since there is no hard line between past and present, many scholars prefer to merge the two fields and to speak instead of *cultural astronomy.* Regardless of how the subject is divided up, the study of people's perceptions of the skies has a deep resonance and helps us appreciate the richness and diversity of human cognition and belief (see COGNITIVE ARCHAEOLOGY).

This said, our knowledge of particular practices is always indirect, whether the evidence we are working with is ethnographic, historical, or archaeological, and questions of METHODOLOGY are highly important. For example, when studying an astronomical alignment (such as a building or temple oriented upon solstitial sunrise) it is necessary to have reasonable confidence that the alignment was actually intentional. This is not self-evident, since everything must, after all, point somewhere. In the 1970s, an abyss developed between two groups of academics regarding the interpretation of British megalithic monuments (see MEGALITHIC MONUMENTS OF BRITAIN AND IRELAND). On the one side were those who paid great attention to STATISTICAL ANALYSIS but little to anthropological theory and tended to argue that "MEGALITHIC ASTRONOMY" was highly mathematically sophisticated. On the other were those who did the reverse and reached the diametrically opposite conclusion: that ancient peoples had no interest in the sky at all.

To get past this impasse, it is important to distinguish between "our" science, which provides tried and tested methods for fairly selecting and assessing evidence, and "their" science, the worldview (ancient, historical, or indigenous) we are interested in (see PALAEOSCIENCE; SCIENCE OR SYMBOLISM?). Those who are mathematically adept but anthropologically naive tend to try to show, in a proprietary way, that people in the past were our intellectual equals by demonstrating that they were capable of sophisticated mathematics and astronomy. The flaw, and also the irony, in this approach lies in the desire to measure the achievements of a past society against the yardstick of our own. This tendency, well known to anthropologists as ETHNOCENTRISM, amounts to putting our own culture on a pedestal. It is necessary to recognize that the worldview we are studying might well be logical enough in its own terms even though it does not conform in every respect to our rationality, since it is built upon different assumptions and principles. A few thousand years is nothing in human evolutionary terms, and thus people living a few thousand years ago were undoubtedly our intellectual equals: however, their way of thinking was different. We pay respect to that difference by trying to understand their way of thinking in its own terms rather than trying to make it conform to ours. It is for this reason that many prefer to avoid using the singular term *astronomy* to describe ancient peoples' interest in the skies, speaking instead, if they use the term at all, of ancient *astronomies.*

All people develop a personal view of the world. It is influenced by their own memories and experiences in which any things that may be perceived—objects, places, events, people and their actions, other living creatures, and plants—can acquire particular meanings, as can the relationships perceived to exist between them. What is more, among the countless things that make up an individual's experience, some come to acquire more significance than others, in a selection process that can seem, to an outsider, highly arbitrary. A "discovery" that seems important to one person may be entirely overlooked or simply of no interest to another. Thus one of the Mursi, a modern group of cultivators and herders living in southwestern Ethiopia, determined the number of days that had elapsed between the planting and first harvesting of his sorghum crop by wearing a cord round his ankle and tying a new knot in it each day. However, those to whom he proudly announced the result were mildly surprised that anyone should have taken so much trouble to deduce something so irrelevant to their daily lives—something that added nothing to their total stock of knowledge about the world.

Groups of people living together do, however, tend to develop common *mindsets*—sets of common perceptions and understandings. These worldviews are reinforced by shared experiences and social convention, and by regular communication, which in small groups is likely to take place by means of a common language. In the framework of modern Western thought, we organize what we perceive in nature according to the principles of Linnaean classification (deriving from the work of the eighteenth-century Swedish botanist Carolus Linnaeus)—that is, into a hierarchical structure of groups (taxa) based upon their observable characteristics. We also tend to believe that the universe is an empirical reality existing independently of the human mind that can progressively be understood through rational argument and scientific experimentation. Other worldviews, however, do not generally classify objects and phenomena into taxa familiar from a Western viewpoint: categories and relationships are not determined by "objective" criteria but simply by whether enough people agree on them. As a result there is generally no clear distinction between the sacred and the mundane, the animate and the inanimate, the empirically real and the fantastic; nor indeed between the terrestrial and the celestial. In traditional cultures, creatures such as fish-man or bird-woman may be seen as fellow beings, every bit as much a part of the perceived universe as entities a Westerner would identify as physically real. As an example, Old Star, chief protector of the inhabitants of the sacred *He* world of the Barasana of the Colombian Amazon, is at once a short trumpet, a constellation corresponding to ORION, the fierce thunder jaguar, and a human warrior.

The sky is a crucial component in practically every indigenous worldview. For earlier peoples and for many indigenous groups around the world today, what we in the modern Western world separate out and categorize as astronomical and meteorological phenomena were an integral part of the environment as a whole. This total environment, including things both real and imagined, *was* the cosmos; the words COSMOLOGY (as widely used in anthropological literature) and *cosmovisión* are broadly synonymous with worldview. In non-Western worldviews, direct associations between the terrestrial and the celestial are commonplace. A good example of this is the BARASANA "CATERPILLAR JAGUAR" CONSTELLATION, whose behavior is believed to relate directly to that of earthly caterpillars, which fall out of trees and provide an important food source at a certain time of the year.

Myths and Monuments

Where we have first-hand informants or can actually still witness long-standing cultural practices, we are in the strongest position to recognize aspects of other worldviews. Examples such as the modern Yucatec Maya village of Yalcobá in southern Mexico, where the structure of the cosmos is reflected in a whole variety of aspects of social behavior, show just how rich and complex these practices can be. Yet ethnographers can be misled by informants, especially if they ask the wrong questions—all too easy if they have very little initial understanding of the nature of the worldview they are studying. Added to this, sacred information is often withheld, or the anthropologist may not be at liberty to pass it on. There is also the additional danger that the ethnographer may succeed, unwittingly, in influencing the very worldview he or she is trying to investigate, so that a subsequent investigator is misled into thinking that certain modern knowledge was in fact indigenous. Finally, most of us are limited to approaching the cultural information indirectly, at best at second hand, which imposes a selectivity that is not of our choosing and a filter—that of the ethnographer's interpretations—through which we are forced to view everything.

Historical accounts, whether by indigenous people themselves or by past ethnographers, are subject to all the problems just mentioned together with some additional ones. For one thing, an author who is no longer alive cannot be questioned, so there is no possibility of clarification or elaboration. For another, in interpreting a historical account it may be critical to appreciate the context in which it was produced.

Ancient written records directly relating to astronomy exist not only among the civilizations of the Middle and Far East (see for example CHINESE ASTRONOMY). Perhaps the most extraordinary example produced in the American continent is the Maya DRESDEN CODEX, a pre-Columbian astronomical (or, more accurately, astrological) almanac. Both its complexity and level of detail are exceptional. In some cultures, other types of recording device encapsulated sacred information, including astronomical knowledge or calendrical data. One intriguing example is the QUIPU, bundles of knotted strings used in the Inca empire. A much more widespread practice, which did not produce any form of written record, was to embed sky knowledge and cosmological beliefs within myths that were transmitted from generation to generation orally. Storytelling may have been entertaining, but it could also have the deeper purpose of passing on wisdom. Creation myths often served to confirm a community's rightful place in space and time, or to establish the genealogical credentials, and hence the social standing, of a king or leader. (Genealogies were not limited to human forbears. The KUMULIPO, a 2,000-line long Hawaiian creation chant composed in the eighteenth century, recounted in detail how chief Ka-'Ī-i-mamao was related, ultimately, to everything in the world.) Some sacred stories were carefully learned and recounted, often in the context of formal ceremonies. Other tales might change in the telling, bringing many variations down to us but leaving intact the essential underlying substance and meaning.

The further we delve into the past, the more we find ourselves limited to the archaeological record—the material remains of past human activity. Silent alignments of stone temples and tombs, interplays of sunlight and shade that light up dark spaces only on rare occasions, symbols with unfathomable meanings but which resemble the sun or moon or familiar groups of stars—these form many of the most famous manifestations of ancient astronomy. But they also present the serious scholar with serious methodological problems. Every oriented structure must point towards *some* point on the horizon, and in all likelihood to one or more identifiable astronomical targets. Similarly, the majority of entrances and openings will let in a shaft of sunlight at *some* time of the year and day. The mere existence of (say) a solar alignment is no guarantee that this meant anything to the builders of a house, temple, or tomb. Since astronomical alignments can—and frequently will—occur completely by chance, we must do more than simply "butterfly collect" them if we are interested in what they actually meant to people in the past. There are two ways of proceeding: either to seek statistical confirmation—for example, by identifying a group of several monuments in which a certain type of astronomical alignment occurs repeatedly—or by finding corroborating archaeological evidence of different forms. An example of the former is the RECUMBENT STONE CIRCLES of northeast Scotland, which have a consistent orientation relating to the moon. Two different examples of the latter, also from Neolithic and Bronze Age Britain, are the THORNBOROUGH henges (large round embanked enclosures) in Yorkshire, England, and the cairns at Balnuaran of Clava in Inverness, Scotland (see CLAVA CAIRNS).

In some cases, such as pre-Columbian Mesoamerica, we have both archaeological and other forms of evidence, including ethnohistory (accounts recorded during the early years of European contact), iconography, and written records (see "BROWN" ARCHAEOASTRONOMY). Integrating these diverse forms of evidence can be a considerable challenge. This problem is illustrated by the prolonged controversy that surrounded the putative Venus alignment at the so-called Governor's

Palace at the Maya city of Uxmal (see GOVERNOR'S PALACE AT UXMAL). Inscriptions on the building attest to a strong interest in the planet Venus, but the apparent orientation of the building toward an extreme rising point of the planet has generated much debate. In ancient Mesoamerica in general, the historical evidence relating to astronomy and calendrics is strong, and the archaeological evidence—for example in the form of alignments—tends to strengthen and corroborate this. If it were not for the accounts of the early Spanish chroniclers, the calendrical inscriptions, and the vital bark books (codices), we would simply have no idea of the sophistication and complexity of Mesoamerican astronomy.

In other places there can be a finer balance. The origins of a piece of oral history are typically much more obscure than the historical context of written records or inscriptions. It can be extremely difficult to separate genuine traditions and stories that stretch back over many generations from more modern inventions or infiltrations. In Hawai'i, a very rich oral heritage existed until the early nineteenth century, of which only fragments now survive (see HAWAIIAN CALENDAR; POLYNESIAN AND MICRONESIAN ASTRONOMY). Yet in assessing the significance of temple alignments in these islands, some of those surviving fragments may contain vital gems of information (see POLYNESIAN TEMPLE PLATFORMS AND ENCLOSURES). They are of uncertain provenance, so must be used with extreme caution, but one would be unwise to simply ignore them and revert to statistics alone.

Where the only available evidence is archaeological, it is possible to use analogies from different cultures where other forms of evidence exist to suggest interpretations. Thus in the 1970s, the Scottish archaeologist Euan MacKie attempted to use the analogy of Maya society to argue (in support of theories, popular at the time, that many of the British megaliths were high-precision observatories) for the existence of highly skilled astronomer-priests in Neolithic Britain (see "MEGALITHIC ASTRONOMY"; "MEGALITHIC" CALENDAR). However, this direct use of ethnographic or historical analogy is generally fraught with problems. Most archaeologists concluded, for a variety of reasons, that MacKie's efforts were badly misguided. On the other hand, analogies can be very useful in challenging assumptions that might have been made too unquestioningly, and hence in suggesting new interpretative possibilities. It is generally assumed, for example, that any people who observed the changing rising and setting position of the sun on the horizon over the year must have understood that this regulated seasonal events. Yet while it is true that some of the Mursi, already mentioned, track the changing rising position of the sun on the horizon, the MURSI CALENDAR is based upon the moon. The sun is regarded as no more reliable a seasonal indicator than the behavior of various birds, animals, or plants. The Mursi example stops us leaping to conclusions about practices in the past by showing us that the range of possibilities is wider than we might have imagined.

In summary, where we have only archaeological evidence to go on, it may be possible to gain insights into prehistoric worldviews by recognizing symbolic associations in the material record. Analogy may be useful in the process of interpretation, but our conclusions will never be categorical. We can only ever have a certain degree of belief that a specific association had meaning to a particular group of people, although our belief may be strengthened or weakened by further evidence.

From Tally Marks to Calendars

How did people begin to make links between different cycles of activity they observed around them and hence begin to understand and control the periodic changes in the natural world as they perceived it? At what stage did they start consciously to plan their own actions in accordance with those perceptions?

Groups of people from the earliest times would certainly have varied their subsistence activities in accordance with the seasons, whether these involved searching for edible plants and animals, fishing, or hunting. But in this alone they were little different from many others in the animal kingdom: many birds, after all, undertake seasonal migrations. Two characteristics that have distinguished humankind for several tens of thousands of years are people's capacity for abstract thought—making connections between things in order to satisfy the desire to make sense of them—and the use of symbolic representation to express ideas. There is ample evidence of the latter in the Upper Palaeolithic, in the form of systematic markings on many small portable objects such as pieces of bone. Their meaning is much debated, but it has been suggested that some at least represented rudimentary lunar calendars—tallies of days or some other sort of symbolic notation relating to the lunar phase cycle. The most famous example is a fragment of eagle's wing found in a cave at Abri Blanchard in southern France, dating to around 30,000 B.C.E. (see ABRI BLANCHARD BONE). Some much more recent, and less controversial, examples of possible lunar tallies among hunter-gatherers are found in rock art from northeastern Mexico. The site of PRESA DE LA MULA, near Monterrey, is one of two petroglyphs that seem to record counts of days stretching over seven synodic (lunar-phase-cycle) months, divided up according to the appearance of the moon. However, these designs were not calendars: they were clearly not intended for regulating future activities. Rather, they were first-hand observational records, with all the vagaries and imperfections this implies.

Counting days, as such, is unlikely to have been an overriding issue for most people in the past. They had to be aware of many different cycles of activity in their lives. One of the most effective ways of keeping track of things is through myth and appropriately timed ritual performance. These were invariably tied in, along with many aspects of living and being, with the unchanging entities in the sky and the ceaseless cycles in which they were seen to move. Stories help describe the world and explain why things are as they are. Ceremonies serve in a very active way to affirm the natural order. Stories and ceremonies also involve an element of control, in that their successful performance, with adherence to strict protocols, is often seen as necessary—even vital—in order to ensure continuity, renewal, and growth. The appropriate rituals may ensure the arrival of the sun on a given morning, or bring about the reversal of the sun's winterward movement so that it will return and give greater warmth again each spring. Whether performed by a lone shaman, by whole communities working in unison, or by a powerful priest with the active participation of a controlling elite, rituals, ceremonies, and other performances can ensure that the order of the cosmos, and of the lives of the people within it, is duly maintained. The Blessingway and other sacred rites of the Navajo people are just one example of performances of this kind recorded in modern times and, in some cases, continuing to the present day, both among native Americans and among indigenous peoples around the world. The Blessingway ceremony serves to ensure good health, prosperity, and so on by preventing misfortune, and involves detailed renditions of the Navajo creation story (see NAVAJO COSMOLOGY).

What may be an extremely old tradition of myths and performances relates to the identification of two bears circling around the northern celestial pole. The evidence to support this assertion, paradoxically, is found in modern oral traditions across Europe. In the Basque country, the bears' motions around the celestial pole are linked to an annual cycle of storytelling and song and dance performances involving whole communities. Other variants are found throughout Europe. Constellation myths within the framework of Greek and Near Eastern thought form an integral part of the modern Western heritage, but the prevalence of indigenous bear myths suggests that two circumpolar bears are star figures emanating from much older cosmological traditions (see SKY BEARS).

In the 1969 book *Hamlet's Mill,* Giorgio De Santillana and Hertha Von Dechend suggested that specific astronomical knowledge—namely the gradual shifting of the entire mantle of stars over the centuries due to a phenomenon known as PRECESSION—had been systematically "encoded" in mythological narratives all over the world over a period of many millennia. There are various problems with the evidence presented in support of this idea, but there is also a fundamental difficulty with the idea itself. It presupposes an almost universal concern in ancient times with a particular concept (precession) familiar to ourselves. This is very different from arguing that some communities in certain places and times might have had stable enough cosmologies—sky knowledge passed down accurately enough over several generations—to have noticed the gradually changing appearance of the sky and attempted to come to terms with it in one way or another.

The point about the sky bears, on the other hand, is that we may be glimpsing an ancient framework of understanding very different from the Western one. According to the American linguist Roslyn Frank, who has investigated the relevant European folk traditions in detail, it was a framework in which earthly bears were venerated. She argues that a human individual playing the role of a bear shaman acted to maintain the cosmic order, organizing the cycle of earthly ceremonial in tune with the annual cycles of the stars. If Frank is right, then we should not look back to some sort of universal, all-prevailing myth or cosmology, diluted with time, but rather to one that always coexisted with many others. One would have to argue that it achieved particular prevalence at high northern latitudes because it brought together what was seen on earth and in the sky in a particularly effective and understandable way; thus it tended to propagate, encountering and mixing with other traditions, and eventually leaving traces visible in folk traditions to this very day.

Another way in which a people can affirm the perceived cosmic order is by carefully timed movement through the landscape. The Lakota people of South Dakota, for example, traditionally keep their subsistence activities in tune with other seasonal cycles by moving from one place to another in an annual pattern that, as they see it, reflects the sun's movement through the constellations (see LAKOTA SACRED GEOGRAPHY). Their annual round combines subsistence activities focused upon the terrestrial movements of the buffalo, with sacred rites focused upon the celestial movements of the sun. In doing so, it ties together earth, sky, and people into a comprehensible whole, thereby keeping everything in harmony. The Mursi of Ethiopia perceive a direct connection between the successive disappearance of four bright stars in the southern sky and events on the ground related to successive floods of the river Omo. This enables them to time their annual migration to the banks of the Omo precisely enough to carry out the vital planting of their crop of cowpeas within a few days of the river's final flood.

Can we hope to find, in the material record, evidence of astronomically timed movement through the landscape in the past? If we could determine the times of year when certain sites or locations were occupied, and if we could spot symbolic links between these places and the sun or stars, then it is certainly possible that this could give us some clues. Symbolism relating to a solstice, at a site that is occupied around the time of solstice, is one possibility. It has been suggested that CHACO CANYON in New Mexico was a focus for sacred pilgrimage for Anasazi (ancestral Pueblo) communities in the surrounding area around the eleventh century C.E. The archaeological evidence for this is supported by archaeoastronomical evidence that people in the outlying communities used astronomical observations to synchronize their convergence upon Chaco. Another, much older, example of a similar phenomenon occurs at THORNBOROUGH, a group of Neolithic henges in Yorkshire, England. Here the archaeoastronomical evidence consists of a series of alignments upon the rising position of the three stars of ORION's belt, suggesting that it might have been the first predawn appearance (HELIACAL RISE) of this asterism that triggered an annual PILGRIMAGE for an autumn festival at the henges.

In modern indigenous societies, we see ample evidence of the various ways in which people strive to harmonize what they do with cycles of events in the natural world. Studies of tally counts, astronomically related myth and ritual performance, and patterns of ritual movement have begun to reveal some of the ways in which this may have been done in the past. CALENDARS—self-consistent systems of marking time—developed from these more rudimentary perceptions of correlations between different cycles of activity in nature, and the desire to keep human activities—ones that we might identify as sacred, mundane, or having aspects of both—in tune with natural events. The cycles of change of the celestial bodies—regular, immutable, and reliable—are clearly of particular importance in this context.

It is commonly assumed that there is a natural progression of calendrical development relating to astronomical observation. The first step is to develop a simple month-by-month calendar based on the phase cycle of the moon, the most obvious cycle in the night sky. However, because there are between twelve and thirteen synodic (phase-cycle) months in a solar year, it follows that in order to keep in phase with the seasons, one needs to have twelve months in some years and thirteen in others. The second step, then, is to take note of phenomena that are related to the seasons, including astronomical ones, using them to keep lunar calendars in pace with the seasonal year by inserting or omitting a month from time to time as required (see LUNAR AND LUNI-SOLAR CALENDARS). The ancient Egyptians, for example, used the first predawn appearance (heliacal rise) of Sirius, the brightest star in the sky, to keep the start of the new year in step with the annual flood of the Nile. Sirius would have been first seen approximately eleven days later in the twelfth month each year. Whenever it did not appear until the last few days of the twelfth month, then an extra or *intercalary* month was added so that it would continue to rise in the final month of the following year.

A seasonally related phenomenon of particular importance is the changing rising or setting position of the sun along the horizon (see SOLSTICES, SOLSTITIAL DIRECTIONS). Once a society recognizes this, they can use it to regulate a solar calendar that is entirely independent of the moon. If the horizon is sufficiently distant and contains a good many distinctive points, then such a calendar can quite easily be kept accurate to within two or three days of the “true” solar year. One of the classic modern examples of a solar horizon calendar is that of the Hopi people of Arizona. As first recorded by the ethnographer Alexander Stephen at the end of the nineteenth century, solar horizon observations were used by the Hopi both to regulate crop-planting activities and to pinpoint events within an elaborate ceremonial calendar (see HOPI CALENDAR AND WORLDVIEW).

The final step in the development of luni-solar calendars is to replace the ad hoc insertion or omission of intercalary months by a systematic procedure. By about the fifth century B.C.E., the Babylonians had developed a fixed system whereby a thirteenth month was inserted into seven different years, in a fixed pattern, within every period of nineteen years (see BABYLONIAN ASTRONOMY AND AS-

TROLOGY). This *Metonic cycle,* named after the Greek astronomer Meton, keeps the lunar calendar in step with the solar year to within an error of just one day in every 200 years.

The Babylonian calendar was an impressive achievement made possible by systematic astronomical observations recorded over many generations. However, ancient calendars do not inevitably follow the progression just described (and even in Babylonia itself, calendrical developments were more complicated). The Mursi yet again provide a good example. They have what, to an outsider, looks like a thoroughly haphazard calendar in which no one ever seems to know for certain what month it is, although everyone believes there are "experts" around. In practice, different opinions always exist, and the calendar is effectively adjusted "on the fly" according to various seasonal markers—though no one is aware that these adjustments are being made. The calendar is completely self-consistent in its own terms, and there is no need for intercalary months. The nearby Borana have a completely different and utterly distinctive luni-stellar calendar that reckons the time of the month and year by observing the moon in relation to the stars, completely ignoring the sun (see BORANA CALENDAR). The *Works* part of HESIOD's *Works and Days* describes farmers' rules of thumb in eighth-century B.C.E. Greece that related exclusively to seasonal astronomical phenomena such as the heliacal rising of stars; the lunar phases are only mentioned in the separate *Days* part. The Roman civic calendar, upon which the modern (Western) calendar is based, only emerged from chaos when it ignored the moon completely (see ROMAN ASTRONOMY AND ASTROLOGY). On the other hand, uncorrected lunar calendars remain of considerable importance to this day, one of the most obvious examples being the Islamic calendar (see ISLAMIC ASTRONOMY). Finally, the ancient Mesoamerican calendar, arguably the most sophisticated and complex of all the world's calendars, operated by combining cycles as diverse as the 365-day year, a 260-day cycle (whose astronomical derivation, if it is astronomically derived at all, remains unclear), and the 584-day synodic cycle of the planet Venus (see MESOAMERICAN CALENDAR ROUND).

In short, there is no inevitable path in the development of calendars. Instead, they advance in diverse ways according to local conditions and needs. This means, for one thing, that they cannot be used as yardsticks of cultural achievement. It also means that they cannot be considered as abstractions, divorced from the social context in which they developed and the social needs that they fulfilled. The Hopi calendar, for example, had (as we would see it) both a pragmatic and a sacred function, but from the Hopi perspective it functioned holistically to ensure the well-being of the community in all respects. Different calendars can have different purposes and even run alongside one another, as—it appears—did the religious and administrative calendars in ancient Egypt (see ANCIENT EGYPTIAN CALENDARS). To the historian or archaeologist, understanding the technical aspects of an ancient calendar is often of limited interest. It is much more intriguing (and often much more challenging) to understand how a calendar operated in its social context, what it meant to people, and what its social implications were.

Modern folk calendars and associated traditions that still exist in many parts of the world, particularly in rural communities, often preserve an inherently holistic worldview, integrating earth and sky in a mixture of what the modern scientist would be inclined to view as rationality and superstition. In the Baltic States of Latvia and Lithuania, for instance, a mixture of prognostications survives that relate people's character, health, and happiness to the phase of the moon at the time of their birth and at important moments in their lives. This Baltic tradition leads to a related issue: the role of ASTROLOGY. The history of astronomy is clearly intimately bound up with the history of astrology; the distinction between the two is only an issue in the context of the modern scientific way of understanding the world. Taking an anthropological viewpoint, we must realize that systems of thought including beliefs that we might describe as "astrological" may themselves constitute ways of understanding the world that are perfectly coherent and logical in their own terms. Thus by considering the biblical skies from the point of view of the astrologers of the time, rather than simply as modern astronomers, a very plausible solution has recently been suggested to the riddle of the identity of the STAR OF BETHLEHEM, which has perplexed astronomers for years.

Ancient peoples generally did not share the modern conception of time as an abstract entity, as a line along which we move through our lives (see SPACE AND TIME, ANCIENT PERCEPTIONS OF). The earliest calendars almost certainly did not come into being as a result of simply conceived astronomical observations undertaken in order to mark the passage of abstract time. They emerged in the context of complex views of the universe in which many aspects of natural and human activity were seen as tied together in fundamental ways. This concept is of vital importance when we try to interpret archaeological monuments that appear to have incorporated alignments marking sunrise or sunset on particular calendrical dates. A fundamental question is: Which regular astronomical events might have been significant to people in the past? Alongside the SOLSTICES, the EQUINOXES are widely assumed to have had inherent significance, yet many investigators have been surprised to discover the absence of equinoctial markers in the culture they are studying. From the point of view of the observers themselves, however, there is a clear difference between the two. The solstices are tangible: at these times, the sun reaches the physical extremes of its motions along the horizon. The SOLSTITIAL DIRECTIONS mark the boundary between those parts of the horizon where the sun can rise or set, only passes over, or is never seen. These define a natural division of the world, as seen from any central point of observation, into four parts. The equinoxes, on the other hand, would in practice only have been observable as halfway points between the solstices. They would generally have been no more likely than any other date in the year to be correlated with any of the other seasonal events that would actually have meant something to people. The midpoint, whether in time or space, seems significant only if one views time and space in the abstract. This is not to deny that particular groups of people in the past may have chosen to divide the year into four roughly equal divisions, but we can not simply assume that the equinox was a significant calendrical date for all.

Interpreting the Archaeological Record

As we have seen, astronomy helps us learn how the cosmos was perceived and understood in the past based on evidence we can retrieve from the material record. The "raw resource" is directly accessible to us: within certain boundaries of error we can reconstruct the positions of the sun, moon, stars, and planets in the night sky at any place and any time in the past. This means that we can readily identify ways in which ancient architecture could have made reference to celestial objects and events. But we must retain a sense of proportion. The astronomical ORIENTATION of a monument, to take an example, might only have conveyed meaning to a few people around the time of its construction, whereas the monument would also have been significant to people in many other ways, communicating meaning by way of its form, the materials used, and other aspects of its location.

In recent years archaeologists have applied a variety of interpretative approaches to the study of how people in the past conceptualized the LANDSCAPE. Yet *landscape* itself is a limiting if not excluding term. Its use reinforces a Western conceptualization of space that divides the world into three distinct parts—land, sea, and sky—and then, more often than not, leads us to ignore two out of three of these. Contrast this concept of landscape with that of the indigenous person who would, without hesitation, identify numerous connections between objects and events in the sky and many other aspects of his or her experience. In dealing with past as well as modern indigenous societies, the term *worldview* should mean exactly that: a people's understanding of the totality of the perceived environment.

The evidence available to the archaeologist consists of a present-day landscape containing scattered traces of past human activity, the end result of centuries—even millennia—of processes of attrition that have served to modify and to destroy. Archaeologists can look at the remains of permanent structures such as houses, tombs, and temples, and examine their location as well as architectural features that seem to express associations with features in the visible landscape and objects in the sky. Other human activities leave traces that are fixed in space, such as rock art (see PRESA DE LA MULA; SWEDISH ROCK ART). Beyond this are numerous types of material evidence, such as small artifacts, which are not fixed in space but may still tell us a great deal in various ways.

A well-tried approach is to try to identify alignments that were deliberately incorporated in architecture or in the location of manmade structures in relation to other prominent features in the landscape. The latter approach has been successful in central Mexico, where the day of sunrise or sunset behind prominent mountains as viewed from certain pyramids and palaces has been found to correlate with calendrical ceremonies performed in sanctuaries built on those mountains. The hilltop palace of CACAXTLA, built in what is now the Mexican state of Tlaxcala in the seventh century C.E., was located directly on a preexisting alignment connecting an older ceremonial site with La Malinche, a prominent volcanic peak still important today as a source of rain and symbol of fertility. The times in the year when the sun rose behind this mountain from Cacaxtla and other temples in the alignment marked two important calendrical festivals and times of ritual pilgrimage. The observances survive, in the form of Christian festivals, to this day.

In this instance ethnohistoric and ethnographic evidence confirms the meaning of symbolic alignments. Where such evidence does not exist, identifying meaningful alignments is much more problematic. Clearly, it is possible to identify alignments between manmade structures and natural features that are in fact totally fortuitous and had no meaning whatsoever to anyone in the past. One possibility is to look for (what seem to us to have been) the most prominent manmade and natural features in the landscape in order to examine possible alignments of significance between them. But even this may be misleading. Mursi sun watchers stand by a favorite boulder or tree to make observations rather than erecting a more permanent marker that would be evident in the archaeological record of the future. Many important dates in the Hopi solar horizon calendar are marked by tiny, inconspicuous skyline notches, while many more conspicuous horizon features are unused. Furthermore, there is generally no obvious natural feature (such as a prominent notch or peak) in the solstitial directions, important as these actually were and are to the Hopi. The reason is that traditional Hopi villages from which observations were made were not located with regard to astronomy and calendrics. Walpi, for example, is perched on a narrow cliff-top mesa: its inhabitants had a given horizon and could not move their position of observation except within very narrow margins in and around the village. They did make precise horizon observations, but this fact would not be recoverable from the archaeological record alone. Any future archaeologist proposing that these particular alignments were significant would be open to the accusation of being highly selective with the data.

In other cases, however, evidence of horizon observations might be more readily identifiable in the archaeological record of the future. The Zuni, for example, had sun-watching stations used for horizon observations prior to the summer solstice. And the inhabitants of the Polynesian island of MANGAREVA established observation places for noting the summer and winter solstices against suitable landmarks, such as adjacent islets or mountain ridges, often erecting stones upon them as foresights. This example bears some similarity to the interpretation of many of the British megaliths, erected in the third and second millennia B.C.E., put forward in the mid-twentieth century by the Scottish engineer, Alexander Thom (see THOM, ALEXANDER). Basing his conclusions upon surveys of many hundreds of STONE CIRCLES, SHORT STONE ROWS, and single standing stones, Thom concluded that "megalithic man" had undertaken high-precision observations of the sun and moon using distant mountainous horizons as the observing instrument. The megaliths, according to Thom, marked where to stand and, in many cases, pointed out the horizon foresight (such as a conspicuous notch between two mountains) that was to be viewed.

Thom's results did not stand the test of time. One reason is that his data set included a wide variety of sites spanning a wide geographical area and a period of some two millennia (see MEGALITHIC MONUMENTS OF BRITAIN AND IRELAND). Subsequent analyses that have been restricted to certain areas during particular periods, and have taken account of a wider range of archaeological evidence, have been more successful. The Scottish RECUMBENT STONE CIRCLES (RSCs) are particularly enlightening in this respect. These are a group of several dozen stone circles confined to an area within about fifty kilometers (thirty miles) of Aberdeen in northeastern Scotland. Their distinguishing feature is a single recumbent stone flanked by two tall uprights, which are without exception oriented between west-southwest and south-southeast, that is, within a quarter of the available horizon. Furthermore, they are consistently aligned upon the midsummer full moon, suggesting that ceremonials were carried out there when the midsummer full moon was passing low over the recumbent stone. This is a conclusion backed up at one excavated site, Berrybrae, where scatters of quartz and burned flint—white stones whose color is similar to the light of the moon—were found in the vicinity of the recumbent stone. However, more recent excavations at other sites have confounded the issue.

The RSCs were modest monuments, apparently serving relatively small farming communities around 2000 B.C.E. Aligning them upon the moon at an important time, and also if possible upon a conspicuous feature in the landscape such as a prominent hill (as is the case at many but not all of the circles), tied them into nature in two different ways. This almost certainly served to reinforce the sacred status of the monuments for the people they served. It seems likely that society in this area at the time never became centrally organized and controlled, and this has bequeathed to us a set of small, similar monuments among which we can easily spot repeated patterns. This enables us to catch a glimpse of some aspects of ritual tradition and worldview—a glimpse that points strongly to the moon as a principal focus of attention. Similar conclusions have been reached in investigations of SHORT STONE ROWS in southwest Ireland.

A step on from identifying and interpreting monumental alignments is to ask why the monuments were placed where they were and not elsewhere. Answering this question involves a detailed investigation of whole landscapes to identify potential alternative locations. Such an investigation was carried out in the late 1980s in the northern part of the Isle of Mull, off the west coast of Scotland. It showed that a set of five stone rows found there, apart from being consistently aligned upon the moon, were all placed so that Ben More—the most conspicuous mountain on the horizon in the area—was on the very margin of visibility, clearly in sight to one side of each row but completely hidden by intervening ground from the other. One suggestion is that the stone rows' main significance was as some sort of symbolic boundary marker between areas from which this (sacred?) mountain was, and was not, visible.

One supposition that emerges from these studies of monuments incorporating astronomical alignments is that many of them became "special" when the astronomical body in question appeared at the appointed place. At these times, their sacred power was surely reinforced. Another way in which a similar effect could be achieved—creating a very considerable visual impact at certain special times—was through the interplay of sunlight and shadow. Widespread evidence indicates an interest in creating carefully orchestrated interplays of shadow and light at sacred places, sometimes producing special effects visible on only very rare occasions. A famous example occurs at the passage tomb of NEWGRANGE in Ireland. Here, for a few precious minutes after sunrise on a few days around winter solstice, the dark interior of the tomb becomes lit up by sunlight shining directly down the passage. Even in the present day, such *hierophanies* can capture the imagination and become the focus of great public spectacles, whether or not they were actually intended by the builders. A case in point involves the pyramid of KUKULCAN (El Castillo) at Chichen Itza. It contains a staircase on each of its four sides, and at the base of the northern staircase is the carved head of a serpent. On days close to the equinoxes, the light of the late afternoon sun falling across the stepped corner of the pyramid creates the effect of a serpent's body, which only "appears" at these times. This spectacle now attracts tens of thousands of visitors. In contrast to Kukulcan, no serious doubts exist that the Newgrange hierophany was actually intentional; though, by its nature, it could never have formed a great public spectacle, since the space inside the tomb was confined. This dramatic effect was intended for the ancestors, or for ancestral spirits.

What was the purpose and meaning of such hierophanies? There is no simple answer, but further clues can be found by looking at more modest examples, often to be found in rock art. By carefully placing rock art designs, sunlight could be made to play across them at certain times, with impressive effect. A number of interesting examples are to be found in California, which was densely populated by hunter-gatherer groups prior to the European conquest. The Luiseño, for example, had an intense ceremonialism, a rich sky lore, and a calendar regulated by various astronomical observations. Although their seasonal calendar was lunar-based, they observed and celebrated the solstices, attaching particular importance to the winter solstice, which they regarded as a time of cosmological crisis. Solar imagery is evident at various Luiseño rock art sites, and light-and-shadow effects have been discovered at three or four of them, more than one involving daggers of sunlight that bisect painted discs.

One of the most famous shadow-and-light phenomena concerns a petroglyph situated toward the summit of Fajada Butte, in Chaco Canyon (see FAJADA BUTTE SUN DAGGER). A carved spiral hidden away behind three slabs of rock leaning against a vertical rock face is occasionally lit up by the light of the sun shining through cracks in the rocks in front of it. Around noon on the summer solstice, however, a thoroughly distinctive dagger of light suddenly appears and bisects the carving. How should this be interpreted? Assuming that the slabs were carefully placed rather than falling into their positions naturally (and there has been some debate on this issue), it appears that a good deal of care was taken in positioning the spirals so that the summer solstice, and possibly other times of the year also, were clearly marked. The location is difficult to access but good for astronomical observation. Comparisons with the practices of historic Pueblos suggest that it might have been a sun shrine—a sacred place where a sun priest came to deposit offerings at certain important times in the ceremonial year. In this sense it would have been far more than a simple calendrical device. It was more likely something that, through its powerful symbolism, helped to affirm the sacredness of this inaccessible place, and by so doing helped to reinforce the power of the person or people who understood its meaning and had the privilege of using it.

As with astronomical alignments, we again encounter a methodological problem: just because we observe a shadow-and-light phenomenon does not mean that it was intended by the builders or had any special significance before our "discovery" of it. Given any pattern carved on a rock, what are the chances that the sun will play across it at some time, quite fortuitously, creating an unintentional effect? In the case of the Chaco petroglyph, more secure interpretations can only stem from wider evidence about Anasazi culture, perhaps with valuable clues from historic and modern Pueblo groups.

A different form of shadow-and-light phenomenon has been noted in Mesoamerica: the so-called zenith tube. ZENITH TUBES are vertical tubes incorporated in specialized ceremonial structures that marked the biannual passage of the sun through the zenith at noon, at which time sunlight could pass directly down the tube and light a chamber below. One of the most impressive examples is found at the ruins of Xochicalco in Mexico, where a tube more than five meters (sixteen feet) long opens into the roof of a natural cave artificially extended to form a rectangular gallery with three central pillars. The use of such tubes for the purposes of astronomical observation cannot be established with certainty but seems likely given the known significance of the ZENITH PASSAGE OF THE SUN in Mesoamerica, both from studies of the ancient Mesoamerican calendar and from modern ethnography.

Displays of light and shadow, especially if they occur only infrequently, can be highly impressive. It is easy to see how they could have conveyed symbolic power, reinforcing sacred associations that formed part of the fabric of the prevailing worldview. Their presence in the archaeological record has the potential to reveal aspects of that worldview to us. The power to impress is conveyed to the modern investigator through direct experience—"being there" and experiencing the event for oneself has proved popular and is useful in generating tentative interpretations. But it also brings dangers. There is considerable potential for us to experience shadow-and-light phenomena that had no significance whatsoever to people in the past.

Great monuments also have the power to impress, none more so than STONEHENGE in England. Over the years it has attracted more than its fair share of theories, from the plausible to the plainly ridiculous. However, the general perception prevails that there was some sort of connection between Stonehenge and the skies, which accounts for its frequent appearance on the front covers of books on ancient astronomy. In the meantime, archaeological excavations have put some of these theories in a more secure context. The bluestone and sarsen circles, constructed around the middle of the third millennium B.C.E., replaced earlier timber constructions built within a circular ditch and bank that had been completed some 500 years earlier. The later stone monument was certainly a place of great power, and the solstitial alignment of the main axis, which all commentators agree was deliberate, represented a shift of several degrees from the earlier orientation. The transformation of the monument from timber into stone, the use of exotic stones from faraway places, and the sheer size and scale of the edifice strongly suggest a process of enriching the ritual symbolism of the site around 2500 B.C.E. to legitimize its place at the center of the cosmos and hence its ultimate power. This transformation probably served in turn to reinforce the earthly power and influence of a social elite. The change in the axis to incorporate the solar alignment was almost certainly part of the same process.

Modern Western science is only one of many frameworks of thought within which people all over the world, from Palaeolithic times to the present day, have gained an understanding of natural phenomena, including what could be seen in the sky. Modern science only seems the pinnacle of intellectual achievement from a Western perspective, and seeing it as such creates a tendency, when trying to comprehend non-Western modes of understanding, to single out particular "advances," seeing them as steps along the road. From an anthropological point of view, it seems stiflingly restrictive to proceed in this way when we can seek a much broader appreciation of different developments in human thought. This can only be achieved by studying the great many ways in which people have striven to comprehend the world that they inhabit and the many different contexts—physical and social—within which particular developments in thought have occurred. This applies just as much to sky knowledge as to all other knowledge. Above all, we need to recognize the magnificent diversity of human worldviews that has existed through time, and to respect them for what they were and are, even though we will inevitably continue to describe them, and try to make sense of them, in the framework of our own.

Using This Book

The entries in this encyclopedia fall into three categories. First, there are those that elaborate upon some of the key *themes and issues* relating to ancient astronomy, many of which have been introduced above. They include, for example, LUNAR AND LUNI-SOLAR CALENDARS, PALAEOSCIENCE, and ASTRONOMICAL DATING. Other entries in this category relate to particular objects or phenomena in the sky and their cultural significance (for example, ORION and LUNAR ECLIPSES). Also included are broad definitions and explanations of key concepts (such as ARCHAEOASTRONOMY, COSMOLOGY, and ALIGNMENT STUDIES), brief descriptions of procedures and techniques (for example, FIELD SURVEY and STATISTICAL ANALYSIS), and a few people who have been important in the overall development of the subject, such as SIR NORMAN LOCKYER and ALEXANDER THOM. The second category comprises *case studies* of a variety of types of human society, from hunter-gatherer groups to urban city-states, and spanning a chronological and geographical range that stretches from Upper Palaeolithic Europe through Polynesia and other remote parts of the world prior to European contact. Though the case studies are far from exhaustive, they have been carefully selected to illustrate particular issues and themes, with an emphasis upon cultures and places that are less well known outside the specialist literature of archaeoastronomy. The final category of entries consists of short, nontechnical explanations of *basic concepts* like SOLSTICES, HELIACAL RISE, and DECLINATION. At the end of each entry is a list of related entries divided into three parts: themes, case studies, and basic concepts. Straightforward definitions of terms are given in the glossary.

We have avoided drawing sharp divisions between *ancient* and *modern*—divisions that only serve to mask the rich variety of human ways of understanding and appreciating the sky. For this reason, we include topics such as CHURCH ORIENTATIONS and ASTROLOGY, which extend into relatively recent and even modern times, together with examples of traditions that live on still among modern indigenous peoples, such as BARASANA "CATERPILLAR JAGUAR" CONSTELLATION, MURSI CALENDAR, and PAWNEE COSMOLOGY.

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A

Aboriginal Astronomy

When Captain James Cook first sailed up the east coast of New Holland (what is now Australia) in 1770, he encountered native people who had little interest in their strange visitors and none whatsoever in trading—people who surprised him by being generally unclothed, constructing little in the way of shelter around their camp fires, and even sleeping in the open. Yet their lifestyle, while short of so many of the conveniences viewed by Europeans as essential, also seemed free from many of the cares that accompanied them. As Cook saw it, the earth and sea satisfied all their needs.

As we now know, the Aboriginal way of life had gradually developed over many thousands, and indeed tens of thousands, of years. Australia's first inhabitants traveled to the continent more than 50,000 years ago from Asia, via the islands of what is now Indonesia. Despite lower sea levels at that time, the journey still involved crossing straits as wide as eighty kilometers (fifty miles) or more. During the long history of the Aboriginal peoples, factors such as climate change almost certainly caused significant upheavals, but by the time the Europeans arrived, Aboriginal groups were to be found in all corners of this vast and largely arid continent. Their lifestyle had become well adapted to an environment that, from a European perspective, was immensely inhospitable. Never settling for long in one place, they lived by gathering food, hunting, and (for people in the coastal fringes) fishing. This hunter-gatherer style of subsistence had never been superseded by agriculture, let alone affected by technological innovation such as metallurgy.

Since Aboriginal culture and tradition had developed independently of the rest of the world for millennia, it is tragic that much of it was utterly destroyed in such a short time after the arrival of the Europeans. It is estimated that at the time of contact there were more than 750 different Aboriginal languages, few of which now survive. Though our knowledge of the ways in which different native Australians viewed the world in pre-contact times is extremely fragmentary, there was clearly considerable diversity between different groups. Yet it is evident that certain fundamental concepts and

Aboriginal engraving at America Track, Kuringai Chase National Park, New South Wales, showing the head and neck of the culture hero Daramulan. (Courtesy of Clive Ruggles)

principles underlay most Aboriginal systems of thought. The most important of these is the *Dreamtime* or *Dreaming*. The Dreamtime is sometimes portrayed as a sort of parallel, more fundamental reality in which ancestor spirits created the world and continue to exist within it. Certain places and paths through the landscape have deep significance within the Dreamtime. The actions of ancestors are re-enacted in many aspects of life, and oftentimes these re-enactments involve being at certain places and following certain paths.

Aboriginal peoples identified strongly with the landscape. Some of the places charged with sacred power were natural, such as distinctive rocks, termite mounds, or water-holes. Others were created, such as "ringed" eucalyptus trees (branches growing apart were trained together again until they rejoined, forming a ring in the trunk). In some locations, "stone configurations"—constructed arrangements of rocks and boulders—also appear to mark sacred places in the landscape, especially in regions devoid of other prominent natural landmarks.

However, to see the Dreaming as something in the Aboriginal mind that is superimposed upon the physical world is a quintessentially Western view of things. From an Aboriginal perspective, the motions and actions of the ancestors are an integral part of the world and can be perceived in places, in the objects that are found there, in the pathways between them, and in events that are constantly happening ("signs," which must be perpetually watched for). Living people also leave their mark by their passage and conduct, not necessarily in a way that a Westerner would recognize as "physical," but by ascribing new meanings to places and pathways in the world. Naturally that world includes the sky. The actions of the ancestors can also be perceived in the appearance and motions of the sun, moon, and stars: sky events affect people, and people affect sky events.

Celestial mythology features extensively in the surviving Aboriginal cultural heritage. A wealth of stories relate to sky objects, including Orion, the Pleiades, the Southern Cross and Pointers, and the Magellanic Clouds. A recent collaboration between ethnographer Hugh Cairns and Yidumduma (Bill Harney), a senior elder of the Wardaman community in Northern Territory, has shown how the night sky acts as a repository of ancient traditions and learning in this community. This learning was taught using *song lines* that cross through the constellations just as the so-called *dreaming paths* pass through the earthly landscape below.

Extrapolating back in time is much more difficult. Among the few tangible remains from earlier epochs, the most ubiquitous are the rock art sites found in several parts of Australia: over 100,000 such sites have been recorded. Their dates are generally indeterminable within wide bounds, although some may be several thousand or even tens of thousands of years old. Some include what are clearly depictions of ancestor spirits, people, animals, and activities such as hunting and dancing, while others are more abstract. To what extent modern practices can inform us about the meaning and use of art in the past is a contentious issue. Some contemporary bark paintings certainly include depictions of the sun, moon, Venus, various constellations, the Milky Way, or the Magellanic Clouds, although in many cases it would be impossible to recognize them for what they are if we did not have informants to tell us. In some cases we know something of the stories to which they relate and the context in which they were used to tell those stories. Rock art, on the other hand, is tied to a particular place. For Yidumduma, rock art sites are places (but by no means the only places) where ancestor spirits reside, and the significance of each is revealed in the context of the whole Wardaman creation story. The sky is an intimate part of this story:

> Dreaming for the cosmos, the land and sky together for people that travel. The Creation routes connected to the people on the wall of the rock, and the connection up on the top, on the sky, down the bottom, and how everything is changing in this country. All the animal[s] and . . . the ceremony of the people in the rock . . . and all these other ones divided from the bottom and up to the top in the sky, with all the stars all part of human life from the sky. (Cairns and Yidumduma 2003, p. 31)

Taken out of context, as this example shows, the complexity of the connections between the content of rock art, its location, and the sky would be quite unfathomable to an archaeologist without an informant to interpret them.

Can more direct links between rock art and the sky sometimes be evident, even where we lack "the big picture"? A number of rock art sites contain inexplicable groupings of round holes or cup marks, which have not, it seems, arisen naturally; and some of these, it has been suggested, could represent constellations. However, it is disconcertingly easy to fit random collections of cup marks with patterns of stars in the sky if one is prepared to be sufficiently flexible in one's selection criteria, so the case remains unproven. There is little other evidence of direct relationships between rock art motifs and the appearance of celestial objects, although it has been suggested that the stylized forms of emu on some panels reflect the shape of the emu in the sky, a conglomeration of dark clouds in the Milky Way recognized as such in a number of places across Australia. John Morieson, an Australian archaeoastronomer, has suggested that a number of stone configurations in northwestern Victoria related directly to the rising or setting sun and incorporated deliberate alignments toward sunrise or sunset in particular seasons in the year.

There is certainly evidence that a number of different Aboriginal groups took note of the annual changes in the position of certain stars or constellations as indicators of seasonal events that affected their food supply. Arcturus is the fourth brightest star in the sky. For the Boorong people of northern Victoria, this star was Marpeankurrk, the ancestor who discovered *bittur,* or termite larvae, a delicious and valuable source of protein available at a time of year (August and September) when other food sources were scarce. Every year Marpeankurrk taught the living people when to find the *bittur* by appearing in the north during the evening. But night by night she appeared for a shorter and shorter time until she disappeared completely—and so did the *bittur.*

Although this is one of many similar examples, there is no evidence of any Aboriginal group having reckoned time using a calendar based, for example, on the phase cycle of the moon. Another curious feature of Aboriginal astronomy—at least, as far as we can tell from the available evidence—is that, despite living in wide open landscapes and having an intimate knowledge of the skies, Aboriginal peoples do not seem to have used the stars to navigate at night. Their astronomical knowledge, and their knowledge of the world in general, was qualitative rather than quantitative. It consisted of a rich network of associations confirmed in myth and tied to places and pathways both in the land and in the sky. Their worldview integrated land, sky, and social structure and kept human action intimately in tune with the cosmos.

Despite our fragmentary knowledge of Aboriginal astronomy, it is of great importance in showing how sky knowledge among hunter-gatherers can be rich and complex, despite leaving little or no trace in the material record. This fact has implications for how we interpret what extremely fragmentary archaeological evidence we have pertaining to astronomical knowledge in Upper Palaeolithic and Mesolithic times.

See also:

Constellation Maps on the Ground; Emu in the Sky; Landscape; Magellanic Clouds; Navigation.

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Abri Blanchard Bone

The earliest indications of the use of a symbolic notation to represent or visualize an astronomical cycle come from the Upper Palaeolithic period. At this time, in addition to striking cave art, engravings were made on small portable objects such as stones and pieces of bone and antler. Thousands of examples are known. A number of these are in the form of series of marks, and several were subjected to meticulous microscopic analysis by the American researcher Alexander Marshack. He concluded that the marks were not a simple decoration but carefully accumulated, often using different tools and techniques, over a period of time.

One famous example is part of an eagle's wing discovered in a cave at Abri Blanchard in the Dordogne valley, France. Dated to around 30,000 B.C.E., it contains a series of notched marks in a serpentine pattern. Marshack proposed that these represent a tally of days. The assumption is that the earliest marks are those in the center of the pattern, and that marks were accumulated around existing ones. By following the line outwards and back and forth, we discover that there are about fifteen marks in each sweep before the direction changes.

The most prominent astronomical cycle is the phase cycle of the moon. In addition to being readily observable, it coincides with the female menstrual cycle. The moon's phase cycle is certainly recognized among modern hunter-gatherer groups, although not necessarily universally (an apparent exception being Australian Aboriginals). The period of the lunar phase cycle (synodic month) is between twenty-nine and thirty days, so one interpretation of the Abri Blanchard bone is that it represents a tally in which the days of the waxing moon are marked off in one direction and those of the waning moon in the other; in other words it forms a rudimentary lunar calendar, maintained for about two months. Marshack suggested a similar lunar-calendar interpretation for patterns on a number of other Upper Palaeolithic portable artifacts.

Several criticisms can be made of the interpretation of the Abri Blanchard bone as a lunar calendar. Two assumptions upon which it rests are that the number of marks between each "turn" in the line was significant and, second, that this represented the period between successive new or full moons. How easy might it be to fit other explanations? How can we judge a particular interpretation against the alternatives? At least one of the turns is not sharp, which gives greater flexibility in interpretation. Two of the lines could easily be interpreted as separate straight lines rather than part of the serpentine pattern. And there is the question of what exactly we mean by "new moon": there is a one- or two-day period each month when the moon is not visible at all (astronomical new moon occurs in the middle of this), but it is the first reappearance of the crescent moon in the evening sky (the popular concept of "new moon") that is the most significant event in visual terms, widely recognized even in the today's world, from small indigenous groups to major religious calendars. Finally, although some of the marks appear round and others crescent-shaped, there is no apparent correlation between the shape of the marks themselves and the lunar phases.

All of these points introduce doubts in the interpretation of the Abri Blanchard bone as a lunar calendar. It is possible to address them by increasing the complexity of the explanation: for example, the left-to-right sequences contain more marks and can be taken to represent the days from full moon to new moon in the popular sense. But the potential for speculative argument seems endless. Indeed, the underlying microscopic evidence that the engravings represent tally marks or some other form of notation in the first place has been vigorously questioned.

And yet the underlying idea—that certain people in the Upper Palaeolithic would have recognized the phase cycle of the moon and may have attempted to record it—seems plausible enough. One approach would be to try to ascertain, hypothetically, how easy we would find it to "recognize" patterns in sets of markings that were in fact unintentional (for instance, caused by people sharpening tools) or had other meanings entirely. The conclusions could then be used as the basis for a formal statistical test. Yet even if lunar tallies or calendars were quite commonplace in the Upper Palaeolithic, they may not have been recorded at all consistently, in which case any attempt to identify sets of calendrical tallies recorded in a systematic way would be doomed to failure.

Studies of some of the many other Upper Palaeolithic engraved artifacts may clarify the issue. One example, another bone fragment known as the Täi plaque, has been interpreted by Marshack as a more sophisticated lunar calendar. And yet more complex designs give us greater flexibility in interpretation. This is not to say that such explanations are necessarily misguided, but rather that assessing them is no trivial matter. Identifying a methodology that will satisfy both scientists and social scientists is a challenge that has yet to be met by archaeologists.

See also:

Methodology; Palaeoscience.

Aboriginal Astronomy; Presa de la Mula.

Lunar Phase Cycle.

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Accuracy

See Precision and Accuracy.

Acronical Rise

Alternatively spelled "acronychal," for example, in British usage. *See* Heliacal Rise.

Acronical Set

Alternatively spelled "acronychal," for example, in British usage. *See* Heliacal Rise.

Alignment Studies

Archaeoastronomy owes its emergence in the 1970s largely to the furor caused by the controversial and often spectacular claims made by Alexander Thom and others about astronomical alignments at British megalithic monuments. Although archaeoastronomy itself soon grew to encompass a much wider range of evidence, "alignment studies" remain at the heart of a great many archaeoastronomical investigations, particularly those concerning prehistoric Europe.

Where we are searching for evidence of astronomical concerns in prehistory, alignments of monumental architecture remain at the forefront of most investigations. Yet alignments can arise fortuitously, since every oriented structure must point somewhere. Hence the importance of repeated trends, which can be identified and/or verified statistically; good exemplars are the short stone rows in western Scotland and the recumbent stone circles in eastern Scotland. (The stone circle at Drombeg in Ireland provides a cautionary case study.) On the other hand, where other types of evidence are available to us (such as written documents or ethnohistory), studies of the significance of particular alignments may be carried out in a broader context with little or no need for statistical verification. A good example of this is the alignment of the so-called Governor's Palace at the Maya site of Uxmal.

The term *alignment studies* is not limited to the architecture of large monuments and public buildings but also includes studies of the layout of cities, as in pre-Columbian Mesoamerica (Teotihuacan, for example) or the ancient classical civilizations, and their possible relationships to celestial objects.

See also:

Archaeoastronomy; "Brown" Archaeoastronomy; "Green" Archaeoastronomy; Methodology; Thom, Alexander (1894–1985).

Drombeg; Governor's Palace at Uxmal; Recumbent Stone Circles; Short Stone Rows; Teotihuacan Street Grid.

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Altitude

Altitude is the vertical angle between a given direction—such as the direction toward a particular point on the horizon from a given place—and the horizontal plane through the observer. A positive altitude indicates that the point being observed is above the observer; if it is below, then the altitude will be negative. Thus the altitude of a horizon point level with the observer is 0°. That of the summit of a high or nearby hill might be as much as 5° or 10°, but that of a sea horizon viewed from a high place might be –0.5° or –1°.

One can also speak of the altitude of a star in the sky, but this will not generally be the same as the angle of the star above the horizon, since the horizon altitude will not normally be 0°.

There is considerable confusion between the terms *altitude* and *elevation.* Elevation is normally taken to mean the height of a given place above sea level, but the two terms are quite often transposed, for example when pilots speak of the altitude of an airplane to mean its height above sea level and use an altimeter to measure it, while some engineers and astronomers use "elevation" to mean "altitude" as we have defined it here.

See also:
Compass and Clinometer Surveys; Field Survey; Theodolite Surveys.
Azimuth.

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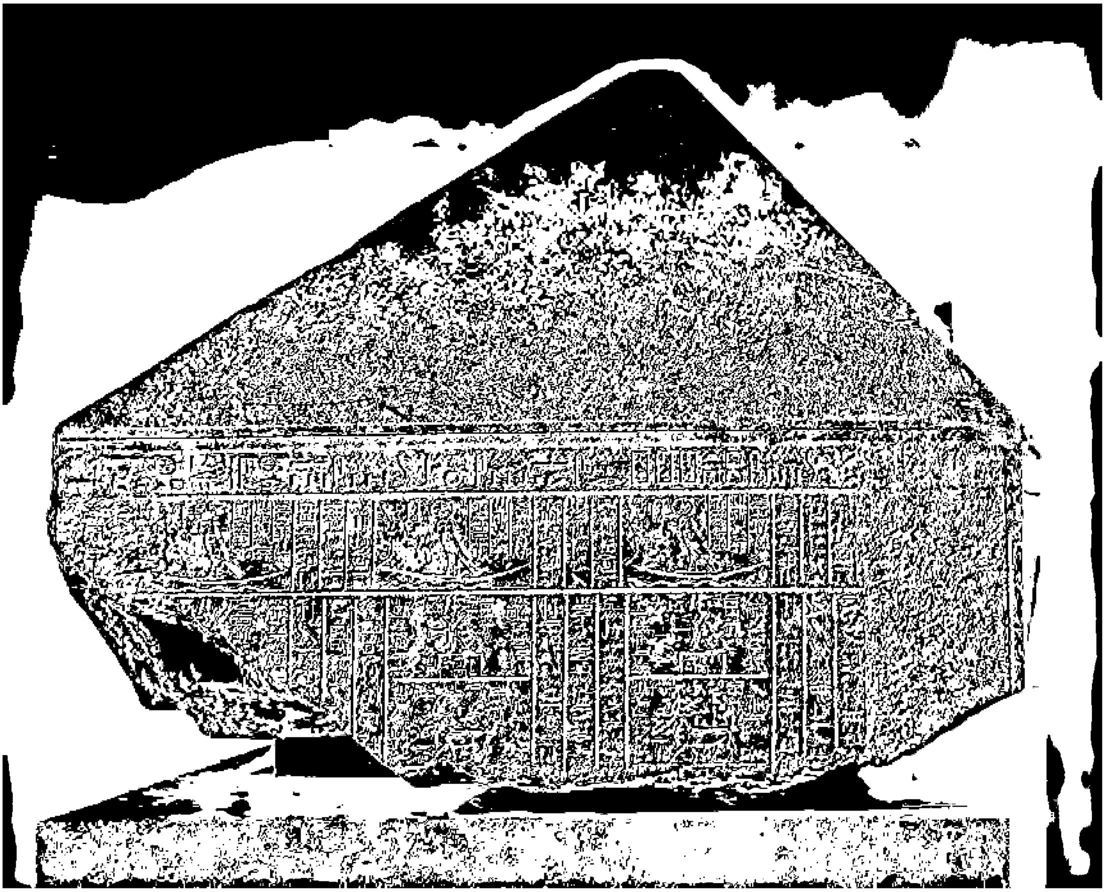
Ancient Egyptian Calendars

The kingdom of Ancient Egypt existed for over three millennia and for much of this time was remarkable in having two different calendars in simultaneous operation. Each arose in response to different social needs and developed a distinct function. At least, this is the standard interpretation of the evidence.

The oldest Egyptian calendar was lunar. It arose in Predynastic times (prior to c. 3000 B.C.E.) from the simple need to keep agriculture in track with the seasons. Twelve lunar phase-cycle (synodic) months only amount to 354 days, so a mechanism is needed for adding an additional (intercalary) month every two to three years in order to keep the calendar in track with the seasons. It is generally supposed that in Upper Egypt (the Nile valley) the calendar was regulated by Sothis, or Sirius, whose first appearance before dawn each year (heliacal rise) coincided with the regular annual flood of the Nile, the most critical event in the agricultural year. Whenever Sothis was not seen until late in the twelfth month, an additional (intercalary) month was added.

Some scholars have argued that a lunar calendar had also developed independently in Lower Egypt (the Nile Delta), but that there it was regulated by observations of the sun. A myth of central importance for the Egyptians was the daily rebirth of the sun god Ra by the sky goddess Nut, who stretched from one side of the sky to the other. This legend was played out



Inscribed gray granite fragment from the "Naos of the Decades," an Egyptian shrine dating to the fourth century B.C.E.*, part of a text giving astrological prognostications associated with different decades (ten-day periods). (H. Lewandowski/Art Resource)*

in the sky. If the Milky Way was seen as Nut herself, as has been suggested, the legend would doubtless have accounted for its shifting position with respect to the rising and setting positions of the sun, according to the time of year. This would have provided the conceptual basis for what we might too easily see as the purely pragmatic process of keeping track of the seasons by tracking the movement of the sunrise and sunset along the horizon. When the two parts of Egypt became unified into a single kingdom, these luni-stellar and luni-solar calendars would have merged.

The Early Dynastic period (c. 3000–2600 B.C.E.) was the time of the first pharaohs and the development of written records. The lunar calendar was fine for regulating agricultural activity on a local scale but became unworkable for satisfying the needs of a complex economy and state bureaucracy. Recording and regulating the movement of perishable commodities, for example, demanded absolute agreement about the date. Yet the beginning of each month, and the insertion of intercalary months, was determined by observation, and observations could differ; as a result, it was often difficult to be certain either about the month or the day in the month. The result was the development of a quite independent civil calendar used for administration purposes. This comprised twelve "months" of exactly thirty days each, divided into ten-day periods known (rather confusingly, given that the word is commonly taken to mean "ten years") as *decades,* followed by a five-day period known as the additional or *epagomenal* days, making a total of 365. Once the calendar was set up, it was defined indefinitely; there was no need to regulate it by observations of nature. It was so fit for its purpose that it survived well beyond the end of ancient Egypt itself and was still being used by astronomers in medieval times.

It may seem surprising to suggest that the lunar calendar did not die out when the civil calendar was introduced. Yet this is precisely what has generally been believed for many years, following the work of the great Egyptian scholar R. A. Parker in the 1940s. According to this view, the purpose of the lunar calendar became the regulation of religious observances. Responsibility for determining the correct month and day within this calendar, and with it the timing of religious festivals, became the responsibility of certain priests. At some stage, and possibly as early as Old Kingdom times (c. 2600–2100 B.C.E.), Egyptians started to use the heliacal rise of other stars to help regulate the calendar and to develop the system of *decans.* These were thirty-six stars or star groups whose heliacal risings occurred in succession, roughly ten days apart—in other words, marking successive decades (ten-day periods) in the civil calendar. This meant that the two calendars could easily be synchronized.

Only recently has a different view emerged, proposed by the Spanish archaeoastronomer Juan Antonio Belmonte. This is that different Egyptian calendars did not in fact coexist. In Belmonte's view, sun observations were used initially to establish the 365-day calendar, but thereafter the dates of lunar-related religious festivals were simply established within this calendar, rather as Christians determine the annual date of Easter to this day.

Whatever the outcome of this debate, it is clear that the decans also heralded a hugely important innovation: they could be used as "clocks" to mark the passing of time during the night. Instead of focusing just on the heliacal rise, that is, on the decan rising immediately before dawn, one simply had to view the risings of successive decans through the night. On this basis, the Egyptians were the first to divide the night into approximately equal time intervals. Theoretically, at the equinoxes, when sunrise and sunset are exactly twelve hours apart, eighteen ideally placed decans should rise between sunset and sunrise at intervals of 40 minutes. In practice, however, the length of the night varies through the year, and twilight renders the first and last risings invisible. Furthermore, it could not have been possible to find stars to use as decans that were precisely evenly spaced across the sky. Finally, the Egyptian kingdom stretched sufficiently far from north to south for latitude to make a difference. The most decans that could actually be seen in one night, during the longest nights of the year around the winter solstice, was twelve. This fact, it is widely believed, led to the concept of the night being divided into twelve "hours," whose length varied through the year, but which were nonetheless a precursor to the modern concept of dividing the day-night cycle into twenty-four equal hours. There is a scholarly consensus on the identification of several of the decans, but the identification of others remains extremely speculative.

The Egyptian civil calendar was simple, useful, and all-pervasive. It worked unfailingly for almost three millennia, and although it gradually slipped with respect to the seasons (historical sources confirm that the civil new year once more coincided with the heliacal rising of Sirius in C.E. 139), this never seems to have created a problem during any particular epoch. Not until the third century B.C.E. was any attempt made to add leap years.

See also:

Lunar and Luni-Solar Calendars.
Coffin Lids; Egyptian Temples and Tombs.
Heliacal Rise; Lunar Phase Cycle.

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Andean Mountain Shrines

Traditional belief systems that still persist in a number of remote Andean villages link mountains, ancestor worship, ritual pilgrimage, and the sea as the ultimate source of water and fertility. The landscape is "animated" in the sense that unusual or prominent features are perceived to have a supernatural aspect. Local communities often regard themselves as the descendents of mountain deities; consequently mountain peaks—and especially volcanoes—occupy a prominent place in their cosmic beliefs and communal rituals. Mountains and mountain gods are seen as the controllers of rain, and their summits sometimes remain an important focus of ceremonial activity today. These metaphysical convictions do have a foundation in the physical world, in that prominent mountains have a strong effect on local meteorological phenomena.

These modern mythologies represent the remnants of belief systems stretching back at least as far as Inca times. Numerous shrines, both Incaic and more modern, have been discovered on hills and mountain peaks in Peru, Bolivia, Chile, and Argentina. Sea shells and river stones were commonly offered to deities for water, but more macabre offerings have also been uncovered: human (including child) sacrifices. We know from the accounts of Spanish chroniclers that elaborate pilgrimages were involved in reaching these sacred places. But the intensity of conviction that motivated the expeditions still defies the imagination. Offerings have been found on mountain peaks as high as 6,000 meters (20,000 feet).

There is every reason to believe that some of the mountain pilgrimages were tied to specific calendrical rituals and that they were astronomically timed. Broadly similar sets of beliefs and practices in central Mexico provide more concrete evidence of calendrical and astronomical associations. However, the specific associations that regulated the Andean rituals remain largely unknown.

See also:
Pilgrimage.
Cacaxtla.

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Angkor

The ancient Khmer civilization flowered in southeastern Asia for over five centuries. A number of interacting and competing kingdoms had existed in the area since the early centuries C.E., and both the Buddhist and Hindu religions had been widely adopted. But in C.E. 802, several of these kingdoms joined together to form a powerful state. The capital, Angkor, situated in modern Cambodia, became the center of an empire that, at its height, stretched over 1,000 kilometers (600 miles) from what is now Burma in the west across Thailand and Laos to central Vietnam in the east, and a similar distance north to south, from the Khorat plateau in northern Thailand both to the tip of southern Vietnam and down the long isthmus toward the Malay peninsula. After the early fourteenth century, the Khmer empire went into decline and Angkor collapsed. However, a new capital emerged downstream. Khmer culture endured and in many respects thrived until the arrival of the Europeans and the establishment of the French Protectorate in the mid-nineteenth century.

The word *Angkor* means "Holy City" in Sanskrit. The arrangement of magnificent buildings and reservoirs (*barays*) that survives to this day resulted from construction projects initiated by a succession of rulers, and includes both Buddhist and Hindu temples, according to the religious persuasion of the king in question. At its heart is Angkor Thom, a huge square compound—some 3.5 kilometers (2.2 miles) on a side—containing a royal palace surrounded by numerous public buildings, platforms, and courts, and including two temple-pyramids, the Baphuon and the Bayon. Angkor Thom is flanked both to the east and west by enormous rectangular reservoirs, each over 7 kilometers (4.3 miles) long and 1.5 kilometers (1 mile) wide. To the south is a small hill, Phnom Bakheng (Mighty Mount Ancestor), with a temple on its summit. Beyond that to the south is the most magnificent temple complex of all: Angkor Wat, arguably the largest and most impressive religious structure ever built. Although it has been a Buddhist temple (*wat*) for many centuries, it was originally dedicated to the Hindu god Vishnu. Scattered in its vicinity, but mostly found close to the western and southern sides of the East Baray, are a number of additional temple enclosures, including three that functioned as Buddhist monasteries.

Although it is Angkor Wat's artistic and architectural splendor that so impresses the modern visitor, many of the temples built there also expressed vital principles of cosmic harmony. Some of these expressions are obvious: the large numbers of towers pointing at heaven; the cardinal orientation of

Angkor Wat, Cambodia. (PhotoDisc, Inc.)

the temple precincts and *barays;* and the westward orientation of Angkor Wat, generally supposed to express a link between death and the setting sun, but possibly symbolizing the direction associated with Vishnu. The central tower of the Bayon—at the center of Angkor Thom, which is itself at the center of Angkor—represented Mount Meru, the dwelling place of the gods, placed at the center of a symbolic model of the cosmos. Other principles and relationships may have been expressed more subtly, encoded numerically and geometrically in a variety of ways. Thus the Bakheng temple, with seven levels to represent the layers of heaven, takes the form of a stepped pyramid supporting 108 towers, symmetrically arranged. The visitor mounting the central staircase on any side, however, can only see thirty-three of the towers—the number of principal gods in the Hindu pantheon. The design of Angkor Wat incorporated alignments upon solstitial and equinoctial sunrise, and it has even been suggested that the dimensions of the central structure encoded, in Khmer units of measurement, the number of days in the year. Although many of the specific suggestions are unproven and controversial, they remain plausible, given the ways in which cosmological principles are known to have been encapsulated in Hindu temples throughout history and still are today.

The author Graham Hancock has gone further, arguing that the entire layout of temples at Angkor had another purpose. It formed a gigantic model on the ground of the constellation Draco, just as (he and others have supposed) the Pyramids of Giza in Egypt modeled Orion's Belt. Although this may sound like a simple extension of the idea of human constructions modeling the cosmos, it is ill conceived at a number of levels. For one thing, the idea of producing literal "maps" of the stars in the sky, as opposed to symbolic models of the gods in heaven, has no known place in Hindu beliefs and practice. In other words, this is an idea totally divorced from the social context in which it is supposed to have operated. Second, the construction of successive temples would have needed to have conformed to a very specific grand plan conceived before any of the building started and strictly adhered to by one ruler after another. Third, in order to make the orientation fit the appearance of the constellation in the sky, one has to assume that the plan was conceived around the year 10,500 B.C.E. Though it is not beyond the bounds of possibility that sacred sites might have been recognized for one reason and then retained their sacredness, it is sheer fantasy to suggest that a fixed plan could have been perpetuated for more than 11,000 years. Likewise, the idea of a "lost golden age" at such an early date flies in the face of well-established archaeological evidence from all over the world.

But how, then, does one explain the apparent fit of the temple positions with the pattern of stars in Draco? The answer is that apparently impressive matches like this can easily arise fortuitously, especially if one is prepared to be selective with the data. There are many temples at Angkor, many bright stars in the sky to choose from, and one can project the curved surface of the sky onto the flat surface of the ground in various ways. Certain temples, such as the Baphuon and Bayon, do not fit stars, and certain bright stars in the relevant part of Draco, such as Eltanin (γ Dra) and Altais (δ Dra), do not fit temples. Furthermore, the fit in the remainder of cases is not always impressive. It is possible to argue that there were inevitable errors in the process of identifying the correct location, multiplicities of purpose, and other difficulties in practice. But these possibilities (for which there is no direct evidence) provide no justification for selecting data arbitrarily in order to obtain more impressive fits. This is a flawed game that one plays at one's peril.

The example of Angkor serves to show the severe dangers of seeking astronomical correlates of spatial patterns in archaeological data too keenly and taking interpretations far too far without heeding the constraint of cultural evidence. We do not need to go to such lengths to acknowledge that astronomical and cosmological symbolism was deeply engrained in this extraordinary group of monuments.

See also:
Cardinal Directions; Constellation Maps on the Ground; Methodology.

Pawnee Star Chart; Pyramids of Giza.
Star Names.

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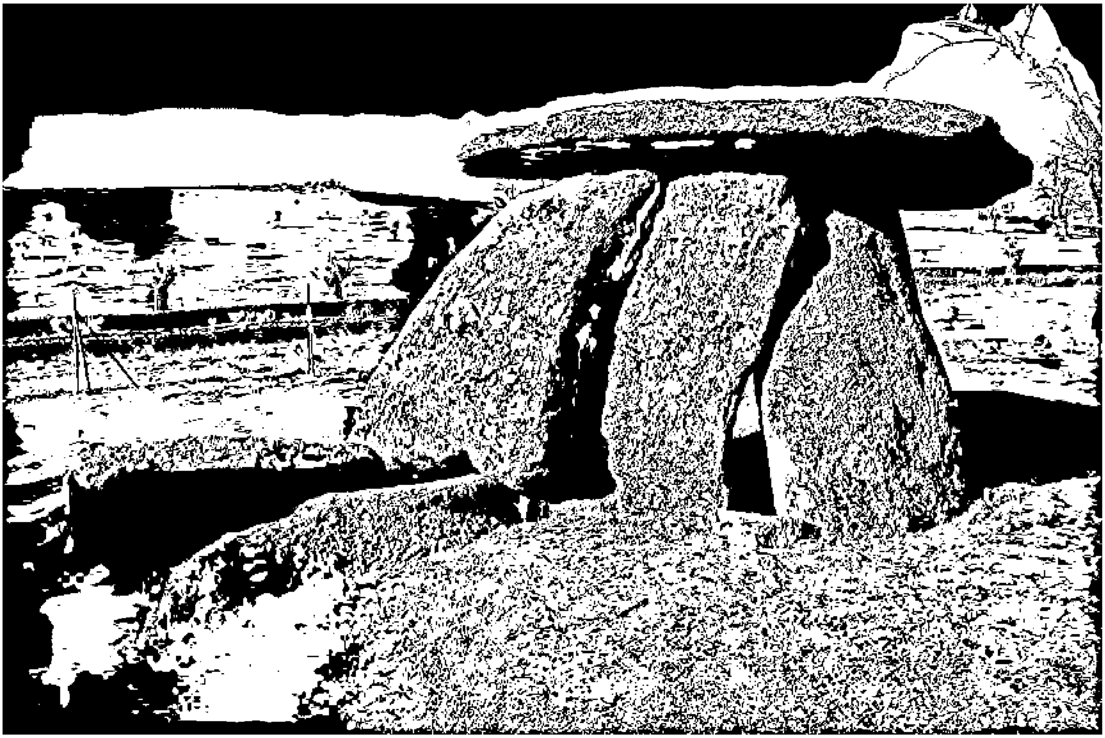
Antas

Antas are a distinctive type of dolmen concentrated in the Alentejo region of central Portugal and the bordering provinces of western Spain. *Anta* in Portuguese simply means "dolmen," but the word has been appropriated to signify a particular method of construction. A large, flattish stone was set in the ground on its side to act as the backstone. Two further slabs were then placed upright leaning against it, one on each side, then a further pair was added with each one leaning against one of the earlier pair, and so on, to form a chamber with a single entrance. Most commonly, seven stones were used in total. A flat capstone was finally placed horizontally on top. Antas vary considerably in size, the smallest chambers being under 2 meters (6 feet) wide and no more than 1.5 meters (5 feet) high, while the largest measure over 5 meters (16 feet) wide and 4 meters (13 feet) high. A magnificent example of the latter is the Anta Grande do Zambujeiro near Évora.

A remarkable feature of the antas is their pattern of orientation. Michael Hoskin, a British historian of astronomy, surveyed 177 of them in the 1990s, using a compass and clinometer to determine their axial orientation (the direction along the axis of symmetry toward the entrance) and their astronomical potential in terms of the declination of the indicated horizon point. According to Hoskin, not a single orientation falls outside that part of the horizon on which the sun rises at some date in the year. Many different groups of later prehistoric monuments within western Europe show distinctive *orientation signatures,* but the implications of this group's signature seem particularly clear: the antas faced sunrise on some day in the year, per-



The seven-stone anta at Mellizo, one of a number found near Valencia de Alcántara in Extremadura, western Spain, close to the border with Portugal. (Courtesy of Clive Ruggles)

haps the day on which construction commenced.

If so, then we must add a qualification. The spread of orientations does not correspond to what one would expect if these dolmens were constructed at random times in the year. If that were the case, we would expect more orientations to fall toward the two ends of the solar range (where its rising position changes less from day to day, and so it spends more days) than in the middle. The actual anta orientations, on the other hand, fall mainly toward the middle of the range. This could be explained in one of two ways. The first possibility is that they were merely oriented roughly eastwards. In this case, the fact that the most extreme orientations happen to fall close to the edges of the solar range, that is, in the solstitial directions, would be seen as purely fortuitous. The other possibility is that tombs were constructed preferentially at certain times of the year, namely spring and/or autumn. Hoskin suggests the latter, arguing that in the spring and summer the needs of agriculture or animal herding would take precedence, but if work on dolmen construction commenced in the fall, it could reliably be completed during the ensuing winter.

See also:
Solstitial Directions.
Prehistoric Tombs and Temples in Europe.
Declination; Solstices.

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Antizenith Passage of the Sun

Just as the sun passes through the zenith, that is, directly overhead, twice a year as viewed from any location within the tropics, so it also passes twice a year through the point directly beneath the observer. This point is known as the antizenith or nadir. The dates of solar antizenith passage occur six months away from those of zenith passage so that, for example, the antizenith passage dates at a location a little way south of the Tropic of Cancer will be shortly before and after the December solstice.

The antizenith passage of the sun may seem a totally esoteric event since, unlike zenith passage, it is not directly observable. Yet some human cultures do seem to have had an interest in identifying the dates of solar antizenith passages and marking them with appropriate observances. It has been suggested, for example, that some of the pillars erected on the western horizon at the Inca capital city of Cusco were aligned upon sunset on the day of antizenith passage.

See also:

Cusco Sun Pillars.

Zenith Passage of the Sun.

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Archaeoastronomy

Archaeoastronomy is best defined as the study of beliefs and practices concerning the sky in the past, and especially in prehistory, and the uses to which people's knowledge of the skies were put. It can be misleading to think of archaeoastronomy as the study of ancient astronomy, since people in the past might have related to the sky in very different ways from people in the modern Western world. For this reason many people prefer to avoid the word *astronomy* altogether. Some speak of *astronomies* to emphasize this point, as is evident in the title of books such as *Astronomies and Cultures* (Ruggles and Saunders 1993).

There have been scientific investigations of the possible astronomical significance of spectacular ancient monuments ever since the later nineteenth century—in the work of Sir Norman Lockyer and Alexander Thom, for example. However, the term *archaeoastronomy* has only been in existence since 1969 and soon thereafter came to take on a much broader meaning. Some popular authors such as Gerald Hawkins, whose book *Stonehenge Decoded* brought Stonehenge into the limelight in the mid-1960s, preferred the term *astro-archaeology,* and this for some became synonymous with *alignment studies,* causing a good deal of confusion that has still not entirely abated. Nonetheless, it was archaeoastronomy that emerged as a recognized academic "interdiscipline" a decade later, marked most significantly by the appearance of two academic journals: *Archaeoastronomy: The Journal of the Center for Archaeoastronomy* in the US and, in the UK, the *Archaeoastronomy* supplement to the *Journal for the History of Astronomy.* It was also signaled by a landmark international conference in archaeoastronomy at Oxford in 1981, the first of a series that has continued ever since.

By that time, archaeoastronomy had already expanded beyond the mere study of monumental alignments. This development was led from the Americas in the 1970s, particularly by studies of astronomy in pre-Columbian Mesoamerica. These studies leaned heavily upon ethnohistorical evidence—the writings of chroniclers in the early years after European contact and conquest—and also, at least in the case of the Maya, upon written evidence in the form of native "books," most notably the Dresden Codex. Alignment studies formed an important part of the new integrated approach to studying Mesoamerican archaeoastronomy but did not drive it. On the other hand, European and especially British archaeoastronomers in the 1970s were largely obsessed with archaeological and statistical reappraisals of Alexander Thom's work and were busy developing formal fieldwork procedures and quantitative techniques for resolving the huge controversy surrounding Thom's conclusions. The American archaeoastronomer Anthony Aveni would later come to characterize these two contrasting approaches within archaeoastronomy as "brown" and "green," after the colors of the covers of the two volumes (*Archaeoastronomy in the New World* and *Archaeoastronomy in the Old World,* respectively) that emerged from the 1981 Oxford conference. Finding the right balance between these two methodological approaches remains one of the major challenges for archaeoastronomy to this day.

Archaeoastronomers, then, are prepared to consider a range of types of evidence—not simply archaeological—and they certainly do not restrict themselves to alignments of monuments. In this sense the word *archaeoas-*

tronomy is misleading, even though it is the term that has stuck. Furthermore, there is no clear boundary between the past and present. Almost from the outset, "brown" archaeoastronomers who studied astronomical traditions within North America realized that myths and traditions surviving in modern indigenous Native American groups could be highly relevant to our understanding of astronomical traditions of the past. When we study reports of ethnographers who worked, say, fifty years ago on a tradition that has since died out, it is clearly pointless to worry about whether to classify this as ethnohistory or ethnography. We may even be able to identify longer threads of continuity stretching from the past into the present, so that, for example, the study of a modern Andean village such as Misminay in Peru may give us some insights into worldviews prevailing in Incaic or even pre-Incaic times. In short, what was once (and sometimes still is) identified as *ethnoastronomy* blends seamlessly into *archaeoastronomy*. Many would prefer simply to combine the two fields of study, referring to them together by a term such as *cultural astronomy*.

Why was archaeoastronomy so controversial in its formative days in the 1960s and 1970s? Partly because Thom's own interpretations, though based upon high-quality surveys of many hundreds of British megalithic sites and supported by rigorous statistical analysis, struck most archaeologists as clear examples of ethnocentrism. In seeing prehistoric Britain as populated by "megalithic man" whom he described as "a competent engineer with an extensive knowledge of practical geometry," Thom was merely seeing his own reflection in the past, the skeptics claimed. In like manner, they pointed out, several prominent astronomers were seeing their own reflections when they described Stonehenge as a sophisticated observatory and eclipse predictor. But there was also a deeper reason. In the 1970s, most archaeologists in the forefront of theoretical developments were trying to describe the actions of human communities in prehistory and the processes of social change in terms of human responses to ecological or environmental constraints. These "processual archaeologists" saw no reason why prehistoric people would have bothered incorporating astronomical alignments into communal monuments.

In the decades that followed, both archaeoastronomy and theoretical archaeology moved forward. Archaeoastronomy ceased to be dominated by astronomers and began to incorporate more archaeologists and anthropologists. This would, at the very least, help to avoid naive pitfalls such as ethnocentrism. As a result, archaeoastronomy began to lose its cavalier attitude toward the body of theory that had been developed (and was continuing to develop) within archaeology and anthropology for interpreting the actions of any past community from what we can find in their material remains. At the same time, the so-called "post-processual" revolution was taking place in theoretical archaeology. A new generation of archaeologists was beginning to confront issues such as cognition. What was going on in people's minds, claimed these interpretative archaeologists, was just as vital in determining people's actions in the past as any environmental constraints. Put another way, how a group of people viewed the world—their cosmology—was just as important in determining their actions as what a modern archaeologist might consider "rational" considerations. This conclusion was supported by numerous case studies from modern indigenous communities such as the Hopi and Pawnee in North America. To speak of "rational" behavior is itself ethnocentric, since what we consider rational is a product of our own worldview.

Why are archaeoastronomy (and ethnoastronomy) worth doing? If we want to understand more about why certain human communities did what they did in the past, then we need to try to understand aspects of their cosmologies—the ways in which they perceived the world. Astronomy is an essential part of nearly every cosmology, because all human communities have a sky, and the sky and the objects in it form an integral part of the perceived world. The objects in the night sky are immutable, regular, reliable, predictable; for communities who did not live inside brightly lit buildings and whose skies were not polluted by modern city lights, they were there for people to watch and contemplate night after night, season after season. They become imbued with meaning.

But what different groups of people perceive as important in the sky, and what significance they ascribe to it, is highly culture-dependent. Two good examples that illustrate this in different ways are the calendar of the Borana of Ethiopia, and the emu "dark cloud constellation" recognized by certain Aboriginal groups in Australia. Nevertheless, people generally try to keep their actions in harmony with the cosmos as they perceive it, which may be the reason many prehistoric monuments were deliberately aligned with objects in the wider landscape, including objects in the sky. Recognizing associations that certain human communities considered important can help us understand something of the worldviews that gave rise to them.

The advantage that the sky holds for us in trying to spot such associations is that it forms a part of the ancient environment that is directly accessible to us, unlike the terrestrial landscape, which is often transitory. We can use modern astronomy to reconstruct, with considerable accuracy, the appearance of the night sky at any place and time, including the motions of the sun, moon, stars, and planets. And this capability offers a considerable advantage, whether we are concerned with myths and beliefs relating to the sky, monumental alignments upon celestial objects, or other kinds of evidence.

See also:

Astro-Archaeology; "Brown" Archaeoastronomy; Cosmology; Ethnoastronomy; Ethnocentrism; "Green" Archaeoastronomy; Lockyer, Sir Norman (1836–1920); Methodology; Thom, Alexander (1894–1985).

Borana Calendar; Dresden Codex; Emu in the Sky; Hopi Calendar and Worldview; Misminay; Pawnee Cosmology; Stonehenge.

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Archaeotopography

One of the criticisms of archaeoastronomy is that archaeoastronomers who investigate the reasons why ancient buildings and monuments were situated and oriented as they are often seem concerned only with the possibility that the main influencing factors were astronomical. But many different considerations, some quite unrelated to astronomy, can determine the orientation of a monument. One possibility is alignment based on prominent topographic features in the surrounding landscape. Accordingly, the term *archaeotopography* was coined by Michael Hoskin in 1997 to describe the collection of orientation data, as opposed to its (exclusively astronomical) interpretation. However, since the term would seem, similarly, to imply a necessarily topographical interpretation, and since topographical and astronomical motivations are only two among numerous possible reasons for orienting a structure in a particular direction, the term is rather misleading and has not been adopted widely.

See also:
Archaeoastronomy; Cosmology; Orientation.

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Astro-Archaeology

This confusing term has sometimes been used as an alternative to *archaeoastronomy* and sometimes to mean the study of astronomical alignments at ancient monuments—in other words, to represent only a segment of the wider endeavor of archaeoastronomy. It has now largely fallen into disuse, at least among academics working in this area.

See also:
Archaeoastronomy.

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Astrology

To a modern astronomer, astrology is anathema. The idea that there can be any direct connection between the configuration or appearance of distant heavenly bodies in the sky and current or future events in the terrestrial world flies in the face of laws of physics that have been established beyond question over many centuries. This is not to deny that in a few cases an astrological relationship might actually have a physical basis: some claim, for example, that a correlation can exist between the growth of plants and the phase of the moon, because the level of moisture in the soil is related to the lunar phase through a tidal effect.

From the perspective of the archaeologist or anthropologist, whose ultimate interest is in human behavior rather than the laws of the universe, whether such an argument is scientifically verifiable or not is not the point. What interests these scientists is the fact that people throughout the ages have drawn direct connections between the appearance of the sky and events on earth, and that this forms an integral part of their understanding of how the world works. Even in the modern Western world, popular astrology represents a widespread perception of how celestial events influence terrestrial ones and challenges the "institutional" view represented by scientific astronomy. Modern astronomers may dismiss astrology as nonsense, but the direct associations it presupposes between celestial and terrestrial events may well be far closer to the ways people throughout history have managed to make sense of the world than the explanations provided by modern science.

Outside the Western scientific tradition there is no meaningful distinction between astronomy and astrology; indeed, archaeoastronomy might equally well be named archaeoastrology. Modern indigenous worldviews (cosmologies) commonly feature the idea that good fortune on earth depends upon keeping human action in harmony with what is happening in the skies, and there is every reason to assume that this has been true since early prehistory.

The term *astrology* can be applied to three rather different but not entirely separable ways in which people have perceived connections between the configuration of the heavens and events on earth: the belief that particular celestial configurations can portend future events; the belief that they can determine or influence the characteristics and lives of people, most commonly at their moment of birth; and the belief that they are directly connected to (that is, influence and/or reflect) current terrestrial events. Each type of perceived connection could provoke a variety of actions in response to certain observed celestial events.

The belief that what is seen in the sky may foreshadow the future—typically stemming, as for the ancient Greeks, from a belief that it can indicate the intentions of the gods—underlies celestial divination: the use of observations of sky phenomena to predict future earthly events. Such a belief is very widespread in human history. Unique, unexpected, and imposing events such as solar and lunar eclipses were widely seen as portents of disaster. But more regular celestial events also indicated auspicious or inauspicious times for planting crops, having children, going to war, and so on. In city-state or empire, astronomers and astrologers were employed to identify good and bad omens for the benefit of their nations and their rulers. This happened in ancient Babylonia, China, Greece, and Rome, as well as in pre-Columbian Mesoamerica. Observation was followed by prognosis (interpretation) and then by action (prescription). A good example of celestial divination is found in the early Chinese artifacts known as *oracle bones*. Oracle bone inscriptions (a subset of which relate to astronomical observations) followed a prescribed format: a preface describing the action taken by the diviner was followed by the resulting prognostication and then by a verification describing what actually came to pass.

Predictability did not necessarily detract from the divinatory power of a celestial event. The motions of the five visible planets are regular and predictable, though quite complex. Planetary astrology, which can assign divinatory significance to the cycles of appearance of particular planets as well as to their positions with respect to the background stars and constellations and even to one another, extends back to Babylonian times. The Maya went to extraordinary lengths to reduce the workings of the cosmos to a series of interacting regular cycles. The Dresden Codex—a surviving almanac containing tabulations of the cycles of appearance of the moon, Venus and possibly Mars, and even of lunar eclipses—seems to have been an attempt to make the various motions of the heavenly bodies predictable. In doing so, the Maya reached a remarkable level of mathematical sophistication, yet their ultimate motive seems to have remained divinatory. For the ancient Chinese, on the other hand, predicting celestial events through systematic observations and recording fell within the domain of calendrics. This discipline acted almost independently of, and in some senses in competition with, astrology. Here, once lunar eclipses began to become predictable around the year 0, they lost their divinatory significance.

The idea that people's lives can be permanently influenced by the celestial—and particularly the planetary—configurations at the moment of their birth is one of the defining characteristics of modern astrology, and also one that modern scientists find particularly indigestible. (It should be said that planetary birth charts go far beyond, and are considerably more complex than, the popular perception of horoscopes based solely upon the sun's position within the zodiac at birth ["birth sign"].) Planetary birth charts have their origins in ancient Babylonia and reached an apex in Greece and Rome. When astrologers began to generate horoscopes, this fundamentally altered their role. Instead of observing the skies and waiting for calamitous astronomical events, they were now required to work out planetary configurations at specified moments in the past, something that demanded considerable technical skill. Given the particularity of the idea of the planetary birth chart as against the myriad ways one might envision the influence of the celestial bodies on human lives, it is surprising that the practice has proved so persistent.

Insofar as it maintains that a person's destiny is determined or influenced by the configuration of the heavens at the time of their birth, horoscopic astrology is actually a form of divination. It also introduces awkward issues about free will: if one's fate is already sealed, there seems little point in trying to alter it. However, variants are evident in modern folklore that largely overcome this problem. Thus in the Baltic states of Lithuania and Latvia, well into the twentieth century, it was commonly believed among rural communities that the phase of the moon at birth influenced various aspects of a person's character—their propensity to strength or timidity, cleverness, long life, a joyful or gloomy disposition, and so on. But such characteristics could be modified throughout life by choosing, for example, the correct phase of the moon for weaning, baptism, marriage, or building a house.

The most fundamental connection between objects and events in the sky and those on earth that we might term *astrological* relates to the here and now. Belief in the direct interconnectedness of things is evident among modern indigenous communities and surely extended far back into prehistory. Modern examples include the Barasana of the Colombian Amazon, who understand that the celestial caterpillar causes the proliferation of earthly caterpillars; the Mursi of Ethiopia, for whom the flooding of the river they call *waar* can be determined, without going down to the banks, by the behavior of the star of the same name; and those native Hawaiians who still carry on the ancient practice of planting taro and other crops according to the day of the month in the traditional calendar (i.e., the phase of the moon). The extent to which such mental connections might be considered astrological is arguable, but if our interest is in the practices themselves, and what was going on in the minds of the people who practiced them, then the question is largely irrelevant—as irrelevant as the question of which practices might have a rational basis in modern scientific terms. What one might choose to term *science* and what one might choose to term *astrology* are both rather subjective in the context of an alternative rationality, and the distinction between them is certainly meaningless.

See also:

Archaeoastronomy; Cosmology; Lunar Eclipses; Science or Symbolism?; Solar Eclipses.

Babylonian Astronomy and Astrology; Barasana "Caterpillar Jaguar" Constellation; Chinese Astronomy; Dresden Codex; Hawaiian Calendar; Mesoamerican Calendar Round; Mursi Calendar; Roman Astronomy and Astrology; Star of Bethlehem.

Inferior Planets, Motions of; Superior Planets, Motions of.

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Astronomical Dating

Is it possible to date an archaeological site by astronomical means? In theory, the answer is yes, for if we can identify an alignment and the intended astronomical target, measure where the alignment points, and then use modern astronomy to calculate where that event occurred at different times in the past, then we can fit the best date to the alignment. Stellar alignments would seem to be most promising, because the rising and setting positions of most stars change significantly over the centuries owing to precession. The rising and setting position of the sun at the solstices and the moon at the standstill limits also alter with time, although by much less, owing to the slow change in the obliquity of the ecliptic.

In practice, however, astronomical dating is rife with pitfalls. The main one is that we rarely have reliable (e.g., historical) evidence to tell us either that a particular alignment was actually deliberate, or what is was aligned upon in the first place. Where we do have historical evidence, we are likely to know the date fairly accurately already. (A case where we do have some historical evidence, but not as much as we might like, and the alignment does tell us something, is the Venus alignment of the Governor's Palace at the Maya city of Uxmal.)

More often, we are dealing with prehistoric structures where we have no evidence other than the alignments themselves. If we find an alignment that we suspect to be stellar, we can try different stars and different dates to see if any combination fits particularly well. The problem here is that if, say, we are willing to consider the fifteen brightest stars and a five-hundred-year date range, then there is approximately a one-in-three chance that we will be able to find a star and a date to fit *any* alignment. It is frighteningly easy, then, to fit a star and a date fortuitously and made all the easier when we consider that only rarely does one single alignment at a particular monument stand out as the obvious astronomical candidate. In order to be fair with the data—one of the most fundamental methodological principles—we should consider all possible alignments. Added to this is the problem of extinction (the dimming of a star at low altitude due to the earth's atmosphere), which may mean that most if not all of our fifteen stars wouldn't have been visible all the way down to the horizon in the first place. If we are willing to postulate (as some people have done) that structures were aligned upon the point of appearance or disappearance of a star rather than its actual rising and setting point, it increases the chances of our being able to fit a date and star fortuitously to any given alignment (especially at high latitudes, where the astronomical bodies rise and set at a fairly shallow angle). Overall, the potential for circular argument is obvious.

Yet despite these problems, there have been cases where postulated stellar alignments can help in the process of dating a site. One relates to the Pyramids of Giza in Egypt and another to a perplexing later prehistoric sanctuary in Mallorca, Son Mas.

Solar and lunar alignments don't suffer from these problems but have others of their own, mainly that the change over time is very small. The change in the declination of the solstitial sun, for example, amounts to only about one arc minute per century. This means that only if we have good reason to suspect that a solstitial alignment had very high precision, such as that envisaged by Alexander Thom at British megalithic sites, can such an alignment be used to indicate a date accurate to within a few centuries. Even then, variations in refraction may provide an insurmountable obstacle.

See also:
Methodology; Thom, Alexander (1894–1985).
Ballochroy; Governor's Palace at Uxmal; Pyramids of Giza; Son Mas.
Declination; Extinction; Moon, Motions of; Obliquity of the Ecliptic; Precession; Refraction; Solstices; Star Rising and Setting Positions.

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Avebury

Situated in Wiltshire, England, a few kilometers south of the modern town of Swindon, Avebury is one of the largest and most impressive Later Neolithic henge monuments in Britain. Built around the middle of the third millennium B.C.E., it measures some 350 meters (1,150 feet) across and surrounds an entire modern village. The outer ditch and bank, when first constructed, were some 9 meters (30 feet) deep and 8 meters (25 feet) high, respectively, and it is estimated that almost a hundred stones encircled the interior. There were also two inner circles, each around 100 meters (300 feet) in diameter. At the center of the northernmost of these was a configuration of three massive stones arranged like three of the four sides of a huge rectangular box, known as the Cove. Running away from two of the four entrances of the henge, to the west and south, were two long stone avenues. Much of the first 800 meters (half mile) of the latter (the Kennet Avenue) survives, but it originally ran for over 2.3 kilometers (1.5 miles), connecting Avebury to a site whose construction had commenced many centuries earlier: a set of concentric timber circles (possibly a roofed building) later replaced by two circles of small stones, known as the Sanctuary.

Surprisingly, given the obvious importance of the monumental landscape in and around Avebury in Later Neolithic times, few astronomical

Part of the great henge and stone circles at Avebury, Wiltshire, England. (Courtesy of Clive Ruggles)

alignments have ever been claimed here. Alexander Thom's only interest in the site was geometrical. The British archaeologist Aubrey Burl has suggested that the Cove was aligned upon the most northerly rising position of the moon, but the few other known examples of coves show no astronomical consistency.

See also:
Thom, Alexander (1894–1985).
Circles of Earth, Timber, and Stone; Hopewell Mounds.

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Axial Stone Circles

Axial stone circles (ASCs), or more correctly axial-stone circles, are a distinctive type of stone circle found only in the southwestern corner of Ireland, in counties Cork and Kerry. Only one other regional group of stone circles bears any resemblance to the axial stone circles: the recumbent stone circles (RSCs) found several hundred kilometers away on the opposite side of the British Isles, in northeastern Scotland. The Irish axial stone circles (ASCs), like their Scottish counterparts, consist of a single stone placed on its side, with all the other stones being set upright. Without exception, this recumbent stone is found in the southwestern or western part of the circle. But unlike the typical Scottish RSC, the recumbent in Irish ASCs is modest in size. The remaining stones in the circle tend to increase (not decrease, as with the RSCs) in height around to the opposite side, where we find a pair of uprights, generally the tallest, known as *portals,* because it is easy to imagine them forming an entrance into the circle. All of the remaining stones are placed symmetrically in pairs about the axis passing between the portals, across the circle and through the middle of the recumbent stone. This distinctive symmetry means, for one thing, that there is always an odd number of stones in these circles (from five to nineteen). Perhaps more importantly, it also emphasizes the axial orientation. This raises the intriguing question of why it seems to have been so important to orient this axis in a westerly or southwesterly direction (taken from the portals toward the recumbent stone).

The nature of the link between the two groups of monuments is unknown. The Scottish RSCs appear to be older, dating perhaps toward the end of the third millennium B.C.E., while the ASCs appear to extend well into the second millennium. However, secure archaeological dating evidence is still scarce. Postulating a direct link, some authors refer to the axial stone circles as recumbent stone circles; others warn against prejudging the nature of the interrelationship between the two groups and argue in favor of a distinctive term for a distinctive group of monuments.

Despite some systematic differences, the strong resemblance—both in form and orientation—between these two geographically separate groups of stone circles is undeniable. It is perhaps surprising, then, that when we look more closely at the individual orientations of the ASCs we find that—quite unlike the RSCs—they were not guided by particular topographic or astronomical considerations in any consistent way. Unlike their Scottish counterparts, where there is a clear preference for a reasonably distant horizon behind the recumbent, the ASCs are found in a variety of topographic situations, some with high ground rising close behind the recumbent and blocking the distant view completely. And unlike the RSCs, where there is a consistent pattern of orientation in relation to the moon, the Irish sites show no consistent pattern in relation to any astronomical body.

The lesson to be learned here is that a variety of considerations may have influenced the location and orientation of any prehistoric ritual monument, including topographic factors (relationships to prominent natural features such as visible mountains, sacred places, water sources, and so on) as

The axial stone circle at Reenascreena South, Co. Cork, Ireland, viewed along its axis in the direction from the portals towards the recumbent stone. (Courtesy of Clive Ruggles)

well as the heavenly bodies. In different places and different times, different considerations might have held sway according to the dominant tradition. While some elements of prevailing traditions may be carried forward from place to place and through time, others may be modified or be abandoned. The sky forms only one part of a much bigger picture, even where we do have clear and consistent astronomical alignments. Whatever the links between these two very distinctive stone circle traditions at the opposite sides of Scotland and Ireland, it is clear that the strong astronomical (and specifically, lunar) associations of the Scottish RSCs were not transmitted across to their Irish counterparts.

The lack of consistent astronomy among the axial stone circles does not necessarily mean that one or two individual examples could not have been deliberately astronomically oriented, for reasons specific to a particular place and time. The most quoted examples are Drombeg, near Ros Ó gCairbre (Ross Carbery) on the south coast of County Cork, a well-preserved circle whose axis points toward midwinter sunset; and nearby Bohonagh, which faces more or less due west and has been claimed as aligned upon sunset at the equinox. However, the fact that Drombeg is the only one of several dozen large axial stone circles with a clear solstitial alignment must raise the possibility that this could have arisen by chance, and the equinoctial interpretation of Bohonagh is subject to certain difficulties that pertain to all putative equinoctial alignments.

See also:
Equinoxes; Solstitial Alignments.
Drombeg; Recumbent Stone Circles; Stone Circles.

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Azimuth

Azimuth means the bearing of a direction—such as that toward a particular point on the horizon from a given place—measured clockwise around from due north. Thus the azimuth of due north is 0°, that of due east is 90°, that of due south 180°, and that of due west 270°. The azimuth of a point one degree to the west of north is 359°. Azimuth is measured in the horizontal plane through the observer. To fully specify the direction of an observed point, one must also specify the vertical angle or *altitude* of the point.

It is possible to specify the position of a star or other object in the sky by its azimuth and altitude, but this will change with time owing to the diurnal motion of the celestial sphere. Even at a given moment, the azimuth and altitude values of a particular star will be different for observers at different places on the earth.

See also:
Compass and Clinometer Surveys; Field Survey; Theodolite Surveys.
Altitude; Celestial Sphere; Diurnal Motion.

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Aztec Sacred Geography

The Aztec (also known as the Nahua, or Mexica) empire—the last of the great Mesoamerican civilizations—dominated the highlands of central Mexico at the time of the arrival of Hernando Cortés in 1519. It had risen to power following a series of military conquests just a century or two earlier and maintained economic control by extracting tributes in the form of foodstuffs and raw materials (as well as personal services) from conquered populations. The Aztec capital of Tenochtitlan, situated at the center of present-day Mexico City on an island approached along three long causeways, had an estimated population of 250,000. The mass sacrifices to their war and sun god Huitzilopochtli, which took place at the great Templo Mayor in the center of the city, are legendary.

The landscape around the Aztec capital is characterized by strings of mountains and towering volcanoes that surround and dominate flat valleys, creating obvious associations between mountains, clouds, rains, fogs, thunderstorms, springs, and rivers. Under the valley floors and mountain slopes are numerous caves created by ancient lava flows. And before time took its toll and the suburbs of Mexico City spread through the landscape, the terrain was also peppered with magnificent human constructions, both the temples of the Aztecs themselves and the conspicuous remains of earlier temples dating back to the Preclassic period (at least as far as the mid-first millennium B.C.E.). This combination created, in the Aztec mind, a vibrant perceived world strewn with the abodes of powerful spirits: mountains were sources of water and rain; caves were entrances to the underworld; and the huge ceremonial center of Teotihuacan with its enormous pyramids, a thousand years old by this time, was itself seen as a magnificent creation of the gods.

Tributes to the gods had to be made in the appropriate place but also at the correct time. One of the most critical actions was to appease Tlaloc, the god of rain and fertility, and persuade him to send water for the year's maize crop. Petitions to Tlaloc were timed in relation to calendar festivals and often involved the sacrifice of children. Thus on the first day of the month Atlcahualo (in the 365-day calendrical cycle or *xihuitl*), or around the middle of February in the Gregorian calendar at the time of the Conquest, the bodies of sacrificed children were thrown into caves close to mountain sanctuaries, since the water was thought to remain there, inside the mountain, until released by the gods as rain. On the summit of Mount Tlaloc itself, at an elevation of more than 4,000 meters (13,000 feet), was a shrine containing an idol of the rain god where the nobles from Tenochtitlan and adjacent cities converged during a great festival in the month Hueytozoztli, at the end of April. Here, a young boy was sacrificed while, in a complementary ceremony taking place at a nearby lake, a similar fate awaited a young girl, who was appropriately dressed in blue.

Many different calendrically timed rituals such as these, taking place all over the Aztec empire, generated a network of relationships in people's minds between sacred places in the landscape (particularly mountains), the activities that took place there, and the timing of those activities. Evidence suggests that those perceptions were reinforced both by the positioning of temples in the landscape and by solar alignments deliberately built into those temples. It has been proposed that the Templo Mayor was (at least approximately) aligned upon Cerro Tlaloc on the horizon to the east, that the sun would have risen more or less behind that mountain on the equinox, and that two prominent mountains on the eastern horizon from Cerro Tlaloc itself, across the next valley, aligned with sunrise on two important days when mountain ceremonies were taking place on that peak. More recent work suggests that the later phases of the temple were in fact oriented upon sunset at the feast of Tlacaxipehualiztli, which coincided with the Julian vernal equinox in 1519 and was duly recorded by the chronicler Motolinia. Whatever the details in this case, the combination of ethnohistorical accounts relating to the nature and timing of ceremonies, archaeological evidence of votive offerings at sites such as mountain shrines, and archaeoastronomical data on orientations and alignments makes a convincing case that many relationships such as these were real enough in the Aztec mind.

See also:

Sacred Geographies.

Cacaxtla; Horizon Calendars of Central Mexico; Mesoamerican Calendar Round.

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rather than shape, as one would expect if they were literal depictions, and there are no symmetrical crescents on the other side of the circle, which one might expect to represent the phases after totality. Furthermore, the crescent sun cannot be viewed directly. It is more likely that these symbols have another meaning entirely. Similarly, a group of petroglyphs on a rock outcrop at Ekenburg in Sweden have been interpreted as a literal depiction of the sky during a total eclipse in 1596 B.C.E. However, this interpretation depends upon a number of unsupported assumptions. Given the likely impact of such an unexpected event on the people of the time, it seems unthinkable that, in less than three minutes, they could have recorded the appearance of the sky in enough detail to then reproduce it faithfully in stone.

Even in some of the great ancient empires and city-states, where literacy permitted detailed records to be kept of a variety of astronomical (and meteorological) phenomena, total solar eclipses could not be reliably predicted and remained greatly feared. In ancient China, for example, records of total eclipses of the sun go back at least to about 700 B.C.E., but even two complete millennia after this date there was no means to predict them. When they did happen, they were taken as particularly disastrous omens for the state, or for the Emperor himself. Babylonian astronomers were the first to discover that lunar eclipses tend to recur after certain fixed periods of time. This enabled them to predict lunar eclipses but not solar ones, which remained a sign of an impending calamity.

Across the world in pre-Columbian Mesoamerica, the Maya almanac subsequently known as the Dresden Codex contained a tabulated record of eclipses that, once again, could have been used to provide warnings of further lunar eclipses, with a reasonable (although probably not good) success rate—but not solar ones. The Maya city-states had collapsed by the time the Europeans arrived, but the Aztecs continued to record eclipses, even after the conquest. The tremendous fear felt by those natives who witnessed a total solar eclipse in 1531 is recorded in graphic detail by the chronicler Fray Bernardino de Sahagún.

The problem with predicting total solar eclipses is that regular cycles (such as the Saros cycle of eighteen years and eleven days, which the Babylonians identified) are only crude. They take no account of various additional, more complex irregularities in the motions of the earth and moon. These small irregularities are relatively unimportant in predicting eclipses of the moon, which affect half of the earth, but are critical if we need to predict the narrow path of totality of a solar eclipse.

Many people have been keen to demonstrate that prehistoric people could predict eclipses. Famously, the Aubrey Holes, a ring of fifty-six pits surrounding the sarsen circle at Stonehenge in England, was interpreted by astronomers Gerald Hawkins and Fred Hoyle in the 1960s as an eclipse-pre-

Desperation among Peruvian villagers on the occurrence of a solar eclipse. Copper engraving, Bernard Picardi. (Bettmann/Corbis)

dicting device. The two astronomers proposed slightly different methods, but both schemes involved wooden posts being moved around the holes in prescribed ways. Both methods would have successfully identified "eclipse danger periods"—periods when a solar *or* lunar eclipse *could* occur—at roughly six-month intervals. Eclipses of the moon could only occur at full moons, and eclipses of the sun at new moons, falling within these danger periods. However, even partial solar eclipses would only occur on average once every two and a half years, and a total solar eclipse would only happen on average once in several generations. Hawkins's scheme only successfully predicted a fraction of eclipses; Hoyle claimed that his own method would have successfully predicted about half. However, further debate about the relative merits of either scheme is unnecessary. The Aubrey Holes are just one of the several Neolithic pit circles known in Britain, of a range of sizes. It is archaeological nonsense to pick this one as a potential eclipse predictor while ignoring the rest.

Few would doubt that total solar eclipses, when they did occur in the past, could have made a huge impression on the people who witnessed them. Where historical or written records exist they give us concrete information about particular eclipse observations and their social impact. But we must beware of letting our eagerness to find notable accomplishments back in prehistory lead us to invent archaeological evidence that is simply not there.

See also:

Astrology; Eclipse Records and the Earth's Rotation; Lunar Eclipses; Power.

Babylonian Astronomy and Astrology; Chinese Astronomy; Dresden Codex; Stonehenge; Swedish Rock Art.

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Solstices

If one were to go to a fixed spot every morning and watch the sun rise beyond a horizon full of distinctive features, such as distant mountains and valleys, it would soon become obvious that the rising position moves along the horizon day by day. During the months of January to May, the daily change is northward, becoming noticeably smaller in early June and finally almost imperceptible, until it comes to stop on or very close to June 21. After this, the motion is southward once again, at first imperceptible, but gradually hastening until by August the change is almost a whole solar diameter each day. By the end of November, the daily progress noticeably slows once again, until the southerly limit is reached on or about December

21. Exactly the same pattern would emerge if one were to watch sunsets rather than sunrises. The dates when the limits are reached, June 21 and December 21, are known as the solstices.

In a location north of the tropics, the farther north the sun rises and sets, the higher it climbs in the sky during the day. The June solstice occurs, as a consequence, in summer. Thus in the northern hemisphere, June 21 is generally known as the *summer solstice* and December 21 as the *winter solstice*. In the southern hemisphere the converse is true. However, as this can cause confusion, especially within the tropics, the terms *June solstice* and *December solstice* are sometimes preferable.

Outside the polar regions, the summer solstice also represents the longest day and shortest night (technically, this may actually occur a couple of days before or afterward, but the difference is negligible). The winter solstice represents the shortest day and longest night. Within the tropics, though, this makes little difference—as one approaches the equator all days in the year come to have the same length.

The solstices are widely recognized culturally. Historically, summer and winter solstice festivals are documented the world over. The winter solstice in particular is a time of death and renewal, a time when, for many human communities, the sun must be halted in its southward (or northward in the southern hemisphere) progress and brought back—for example, by shamanistic intervention—to enable a new growing season. The indigenous Chumash of California were just one of many peoples who held a major ceremony at this time because they believed human intervention to be necessary in order to maintain the delicate balance of nature. Similar principles may well have motivated a variety of rituals and ceremonies held at and around the time of winter solstice, such as the Hawaiian *makahiki* and the Incaic *Inti Raymi*. Pagan solstice festivals underlie the timing of the Christian festivals of the feast of St. John and Christmas.

See also:

Christianization of "Pagan" Festivals; Solstitial Alignments; Solstitial Directions.
Cusco Sun Pillars; Hawaiian Calendar.
Obliquity of the Ecliptic.

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Solstitial Alignments

The term *midsummer* is loosely applied: it derives from the common name, *Midsummer's Day*, for the feast of St. John, which was timed to coincide with the earlier pagan festivals associated with the summer solstice. *Midsummer sunrise,* then, really means "sunrise at the summer solstice." Likewise, *midsummer sunset* means "sunset at the summer solstice," and midwinter sunrise and sunset refer to sunrise and sunset at the winter solstice.

The direction of midsummer sunrise is always in the northeast quadrant of the horizon for an observer in the northern hemisphere (southeast in the southern hemisphere), but the exact azimuth depends upon the observer's latitude and the altitude of the horizon in that direction. The same applies to midsummer sunset (northwest in the northern hemisphere, southwest in the southern hemisphere), midwinter sunrise (southeast in the northern hemisphere, northeast in the southern hemisphere), and midwinter sunset (southwest in the northern hemisphere, northwest in the southern hemisphere). The only exceptions to this rule occur in the Arctic and Antarctic regions, where the midwinter sun never rises and the midsummer sun never sets.

A great many architectural alignments upon midwinter sunrise have been noted from a variety of places and times. The most famous is the alignment of the passage at Newgrange passage tomb in Ireland, built in the late fourth millennium B.C.E. Similar—in the sense that sunlight only penetrates into a dark space just after sunrise at the winter solstice—but very much older is the palaeolithic cave at Parpalló in eastern Spain. If deliberate, this alignment may date back as far as 19,000 B.C.E.

Midsummer sunrise alignments include what is arguably the most famous solstitial alignment of them all, along the axis of the sarsen monument at Stonehenge in England, toward the Heelstone. Ironically, though, it is quite likely that the alignment in the opposite direction, toward midwinter sunset, was of greater significance to the builders.

Alignments upon sunset at one or the other solstice seem to be no less common than those upon sunrise. A well-known example from North America is the Serpent Mound, a 180-meter- (600-foot)-long serpent-shaped effigy mound in southern Ohio, whose head faces the direction of midsummer sunset. Midwinter sunset at Kintraw in western Scotland was one of the earliest claimed examples of a high-precision sightline using a prominent notch in the natural horizon as a foresight. But that claim has not withstood the test of time.

Other controversial examples of solstitial alignments include the Bronze Age site at Brainport Bay, again in Scotland, where a fierce debate arose about whether the alignment of archaeological features, indubitably oriented upon midsummer sunrise, was precise and "calendrical" or less precise and "ceremonial." The circular sanctuary of timber posts at the Dacian sanctuary of Sarmizegetusa Regia in Romania (late first millennium B.C.E.) is said to face midwinter sunrise, but here the problem is that the alignment exists only in a theoretical sense, since the high horizon in the relevant direction displaces the actual direction of sunrise on the shortest day by some ten degrees along the horizon.

The significance of the solstitial directions is often cosmological rather than practical/calendrical, although the two are not mutually exclusive. In Hopi tradition, the main importance of the solstitial directions is that they define the fundamental divisions of the world into four parts. However, observations of the changing position of the rising and setting sun are also crucial in regulating their elaborate seasonal calendar. This includes, on the solstices themselves, laying prayer sticks on shrines that are themselves placed in the landscape along the solstitial directions.

A key issue is the extent to which we find solstitial alignments because we are looking for them. Nobody would deny that the directions of sunrise and sunset at the solstices are hugely significant in many cultures; the question is the extent to which we approach other cultural traditions armed with a "toolkit" that reflects our own predilections and preferences, and whether this can make us (perhaps unwittingly) selective with the evidence and hence biases our interpretation. To give just one example, the solstitial orientation of the Big Horn medicine wheel in Wyoming, when first announced in the 1970s, engendered much debate because of the suspicion that archaeoastronomers were simply extending the techniques and methods of British archaeoastronomy uncritically into North America. In general, such issues can only be satisfactorily addressed by paying careful attention to field methodology, the cultural context, and the broader archaeological/historical evidence of the site.

See also:

Christianization of "Pagan" Festivals; Methodology; Solstitial Directions.
Brainport Bay; Hopewell Mounds; Hopi Calendar and Worldview; Kintraw; Medicine Wheels; Newgrange; Sarmizegetusa Regia; Stonehenge.
Altitude; Azimuth; Solstices.

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Solstitial Directions

The direction of sunrise at the June solstice represents the northernmost limit of the range of horizon, centered upon east, where the sun will rise on different days through the year. Similarly, the direction of sunrise at the December solstice represents the southernmost limit of this range. Likewise, the directions of sunset at the June and December solstices represent, respectively, the northern and southern limits of the western range of horizon where the sun sets at different times of the year.

Everywhere on earth apart from the polar regions, the directions of June solstice sunrise and sunset, and of December solstice sunrise and sunset, fall respectively within the northeast, northwest, southeast and southwest quadrants of the horizon. These four directions divide the horizon into four distinct parts. The eastern part represents the range of horizon within which the sun always rises; everywhere in this range is a point where the sun will rise at some time during the year. Similarly, the western part represents the range within which the sun always sets. In northern temperate zones, the southern part represents the horizon the sun passes over each day; the direction of the sun in the middle of the day. Things facing in this direction will be open to the light of the sun. The north, on the other hand, is a "dark" direction. (The properties of the north and south parts are reversed in the southern hemisphere.)

Each of these four directions, in other words, has distinct properties and, in different human societies, can acquire distinct cosmological connotations. In one type of quadripartite cosmology (perceived division of the world, as viewed from some central place, into four parts), the boundaries between the different quarters of the world are formed by the solstitial directions. One example of this is the worldview of the Hopi people of Arizona. Another example is the layout of the Andean village of Misminay. It can be misleading to speak of a "quartering" of the world, since the four "quarters" are generally nowhere near equal in size: in fact, equal quarters are only possible (depending upon the horizon altitude) at latitudes of around fifty-five degrees (north and south). Closer to the equator, the east and west parts become narrower and the north and south parts wider. At the equator itself, the east and west parts are only about 47 degrees wide, and the north and south parts are 133 degrees wide.

As one approaches the polar regions, the northern and southern "quarters" rapidly shrink away, and in the polar regions themselves the quadripartite model is not applicable at all. Here, every part of the horizon is the rising or setting point of the sun at some time in the year. Indeed, there is a period around the winter solstice when the sun never rises above the horizon at all, and a period around the summer solstice when the sun never sets. The length of this period depends upon the latitude, but it is clearly a critical time for indigenous groups living in northern polar regions, such as the Inuit.

See also:
Cardinal Directions; Solstices; Solstitial Alignments.
Hopi Calendar and Worldview; Inuit Cosmology; Misminay.
Altitude.

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Somerville, Boyle (1864–1936)

Henry Boyle Townshend Somerville was one of a handful of keen amateur astronomers and surveyors in the early part of the twentieth century who extended the work of Sir Norman Lockyer by carrying out their own surveys of megalithic monuments. Having risen to the rank of vice-admiral in the Royal Navy, he retired in 1919. After he returned to his native County Cork, he was responsible for the first published archaeoastronomical surveys and interpretations of a number of Irish chambered tombs, stone circles, and rows. It was he, for example, who first drew attention to the solstitial orientation of the stone circle at Drombeg.

Somerville is best known, however, for first drawing attention in 1912 to the possible lunar orientation of some of the standing stones at Callanish on the Isle of Lewis, Scotland. One consequence of his paper on Callanish, published in the *Journal of the British Astronomical Association,* was to trigger the interest of Alexander Thom, who went on to become one of the most influential twentieth-century figures in the field. More fundamentally, though, it contained the first suggestion that a prehistoric monument might have been aligned upon the horizon rising or setting point of the moon, not just of the sun or stars. This initiated a line of inquiry that is still bearing fruit today among the Bronze Age monuments of Scotland and Ireland, in particular the Scottish recumbent stone circles and some of the short stone rows found in western Scotland and western Ireland.

Somerville was murdered in 1936 by Irish republican activists, who saw him as encouraging Irish recruits into the British armed forces.

See also:
Lockyer, Sir Norman (1836–1920); Thom, Alexander (1894–1985).
Callanish; Drombeg; Recumbent Stone Circles; Short Stone Rows; Wedge Tombs.

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Son Mas

Scattered around Mallorca, the largest and most mountainous of the Balearic Islands in the western Mediterranean, are a number of walled sanctuaries built during the first millennium B.C.E. that seem to have been the setting for various ritual activities. Son Mas, near the northwest coast, is one of the largest of them but seems to have been in use for a far longer period: radiocarbon dates stretch back into the third millennium B.C.E. However, there is a curious gap around 1700 B.C.E., when the site seems to have been abandoned for several centuries for no reason that is apparent from the archaeology, before being rebuilt and reoccupied.

The reason that the earlier sanctuary was so precipitously abandoned remained unexplained until the site was studied archaeoastronomically. Like the taulas of Menorca, it faces south, but in the direction of a nearby valley flanked by steep hills. This is indicated by a curious, artificial groove cut into the side of a large upright boulder in front of the sanctuary. When the Southern Cross and Pointers appeared down low in the southern sky, passing almost horizontally, from east to west, they would have passed across this valley and hung spectacularly in the sky just above it. But due to precession they would have gotten gradually lower century by century until they were beginning to disappear in around 1700 B.C.E. The result, quite plausibly, would have been a crisis, and it was that which caused the sanctuary to be abandoned.

See also:
Taulas.
Precession.

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Space and Time, Ancient Perceptions of

Long before the invention of writing or the construction of observing instruments, people made sense of the world by linking objects, events, and cycles of activity, both on the land and in the sky. The regular cycles of the skies were often vital in developing notions of temporality, in the sense that they were used to regulate both practical and ritualistic aspects of human activity and played a crucial role in the development of calendars. But this is a very different matter from saying that astronomical periodicities were used to measure units of time, because this assumes an abstract notion of time that may not be appropriate in a non-Western worldview. The same can be said of an abstract notion of space.

For us, time progresses along a line and provides a backdrop against which we live our lives, constantly measurable from calendars and clocks that have become divorced from the physical, observable phenomena in the natural world that once generated them. Likewise, we measure our position in space using maps or GPS receivers that fit comfortably in the hand and, at the touch of a button, deliver our spatial coordinates to within a few meters.

Prehistoric peoples and others in the past who lacked such devices would have been no less aware of the passage of time. The basic needs of survival and subsistence would have forced them to keep their own actions in tune with various regularly recurring events going on in the natural world around them. It is also likely that the regular cycles of the heavens, starting with the most obvious one of them all—the phase cycle of the moon—provided a key point of reference for many and led to the eventual development of early calendars. But we must be careful not to approach the issue too naively. The passage of time (as we would think of it) might have been conceived in many different ways. One of the most fundamental conceptual distinctions is between circular and linear time—the one implying an endless perceived repetition of regular events and the other a single history and future. The ancient Maya are noted for having used both conceptions in parallel, in the form of the Calendar Round and the Long Count. Even the distinctions between past, present, and future break down differently in many other systems of thought.

Similarly, there are numerous ways of perceiving the world that differ from our view of things separated by empty space, from which stems our own idea of space as an abstract backdrop. Notions of the spatial interrelationship of things were inherently contextualized in places and paths with particular qualities and meanings. Furthermore, spatial and temporal attributes of things were intricately bound together in many ways, with the distinction between them (as we would see it) rather blurred. Thus, for the Lakota, the names and meanings of some places changed according to the time of year as they followed the buffalo through the landscape, mimicking the passage of the sun through the sky. The Aztecs, it has been claimed, linked the mountain dwelling of the rain god Tlaloc, the time when the sun rose in line with this mountain as viewed from an ancient pyramid (Cuicuilco), and the time when child sacrifices should be offered to Tlaloc in order to ensure rain and fertility in the coming growing season. And more generally, horizon calendars such as those of the Hopi, or those thought to have operated in central Mexico in pre-conquest times, function by directly associating time (a particular calendar date) with place (the point on the horizon where the sun rises or sets on the day in question).

Although such arguments give us a number of reasons for seeking astronomical alignments in the prehistoric context, they also provide a warn-ing against pre-judging potential horizon targets of astronomical significance. Thus, while the solstitial directions have an obvious physical reality (as the limiting positions of sunrise or sunset on the horizon), the equinoxes, in general, do not. They are commonly taken as self-evident horizon targets, but in fact they only make sense as half-way points between the solstices in space and/or time, and this implies an abstract view of either or both. For a Neolithic Briton standing in a sacred stone circle, the date when (say) a crucial crop should be planted, or when the sun rose behind a particular sacred mountain—both very concrete associations (though of very different types)—are much more likely to have been significant than the abstract equinoxes. This makes it much more difficult for the modern archaeoastronomer to determine whether any stone circles intentionally incorporated symbolic alignments upon sunrise on significant days, since different days are likely to have been significant—and so the "targets" would have differed—from one stone circle to another. Only solstitial alignments could show up consistently in a statistical analysis of several sites taken together.

See also:

Calendars; Equinoxes; Methodology; Sacred Geographies; Solstitial Directions; Statistical Analysis.

Aztec Sacred Geography; Hopi Calendar and Worldview; Horizon Calendars of Central Mexico; Lakota Sacred Geography; Maya Long Count.

Lunar Phase Cycle.

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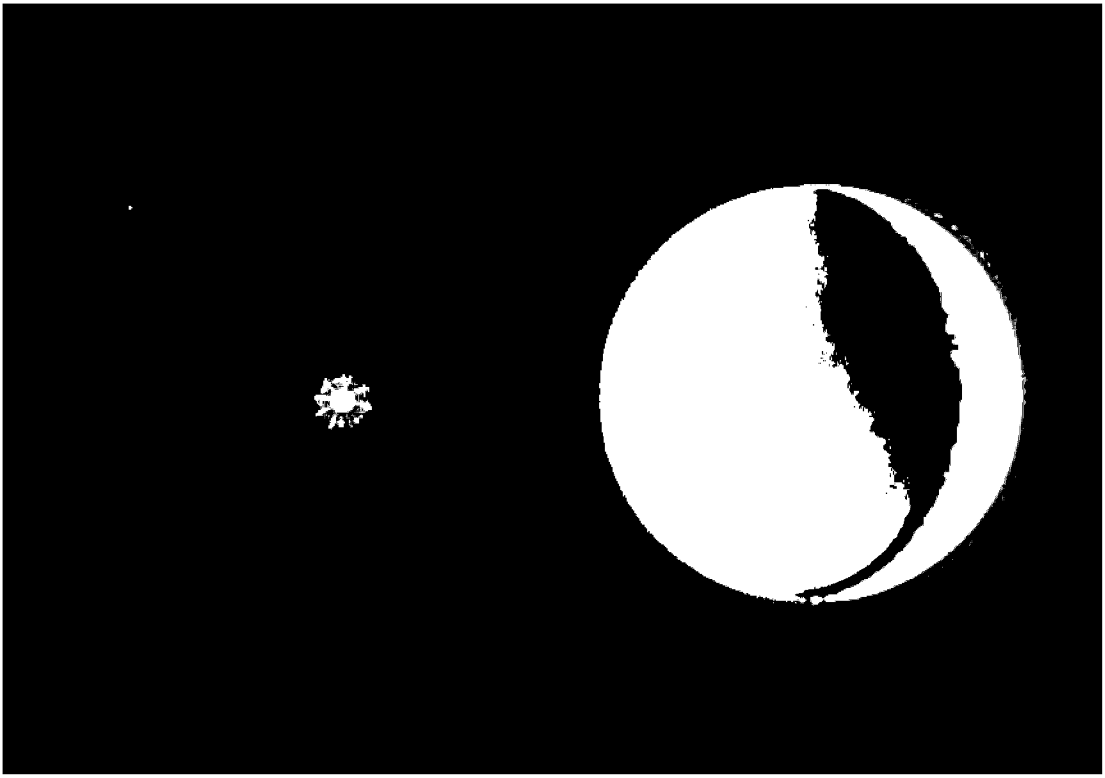
Star and Crescent Symbol

A conjunction of the thin crescent moon and the planet Venus is one of the most striking sights in the sky—even visible within a modern city where the nighttime stars are all but forgotten. The spectacle of these two conspicu-



The planet Venus (left) near a crescent moon. Earthshine illuminates the rest of the moon's disk. (Roger Ressmeyer/Corbis)

ous objects hanging close together in a clear blue (and otherwise quite empty) sky, either in the early evening or the early morning, is likely to have given rise to what is one of the best known and most widespread celestial icons—the star and crescent symbol. In various forms it can be found on the flags of several modern Islamic countries, including Turkey, Pakistan, Algeria, and Azerbaijan; on modern coins from European countries such as Italy and Romania; on coins from ancient Rome, Greece, and Persia; and even in prehistoric rock art from various parts of the world.

The star and crescent is mostly widely recognized in the modern world as a symbol of the Islamic faith, although its origin in this context is much older. It originally passed into several Islamic countries from the Ottoman Empire, and its use within what is now Turkey can be traced back to the third millennium B.C.E. Although it is often claimed that the symbol (in this context) owes its origins to a particular astronomical event, several different candidates have been proposed, and there is really no firm evidence to support any of them.

Elsewhere, where the symbol arose in quite independent cultural contexts, the motivation is most likely to have been one or more sightings of a conjunction of the crescent moon and Venus. This was an event that was spectacular but not unduly rare. And one of the most famous rock art designs in North America including a star and crescent, the so-called "supernova petroglyph" on a rock overhang in Chaco Canyon, New Mexico, is actually a set of four symbols used to mark a sun-watching station.

See also:
Symbols.
Chaco Supernova Pictograph.
Inferior Planets, Motions of.

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Star Compasses of the Pacific

Micronesian and Polynesian navigators used the stars in different ways to help them find their way across the open waters of the Pacific Ocean at night. One method was to learn the sequence of stars that would rise or set in the direction in which one wished to sail—the relevant *star path* or *kavienga* (as it was known in Tonga). The New Zealander David Lewis recorded a few surviving stone structures used for committing a given star path to memory. A single sighting stone in Tonga and two sets of sighting stones in the Gilbert Islands (Kiribati) farther to the north seem to have been set up to mark the directions to various distant islands. (The direction marked was usually somewhat displaced from the actual azimuth of the target island, so that landfall could be achieved by running with the prevailing wind and current.) By sighting along one of these lines sufficiently often and for sufficiently long periods, the novice navigator would come to recognize the succession of stars that marked a particular course. On the island of Beru in Kiribati, Lewis observed the continuing use of a *stone canoe* for a similar purpose.

When traveling greater distances, following more complex courses, or exploring rather than traveling to predetermined and familiar places, navigators needed a wider knowledge of the stars in order to set different courses from different locations in the ocean. The difficulty is that there are so many stars in the sky that to memorize the rising and setting positions of many hundreds of them would surely be impracticable. One Micronesian example of a *star compass,* which was analyzed in detail by the ethnographer Ward H. Goodenough in the 1950s, overcame this problem in a clever way. (It existed in a number of slightly different forms among the Caroline Islands of the western Pacific, although the underlying principles are common to all the variants.) The Carolinian navigator typically relied on just fifteen reference stars or star groups whose rising and setting positions marked thirty directions around the horizon. The north and south directions, in addition, were indicated by Polaris and the upright Southern Cross. The relative positions of these thirty-two guide points around the horizon were carefully memorized: the spacing was not particularly regular, but then it didn't need to be.

In practice, at a given time on a given night, few of the guide stars would generally be anywhere near to rising or setting, and many would not be visible in the sky at all. However, the Carolines are situated quite close to the equator, and the paths of the stars through the sky in this region are more or less vertical (this is only not the case in the vicinity of the celestial poles). This means that it was relatively easy to trace the paths of visible stars down to the horizon. This technique provided a number of reference points. The experienced navigator could then fill in the gaps and deduce the positions of all of the thirty-two guide directions that constituted his mental compass in order to orient himself.

No such detailed accounts exist of star compasses in Polynesia, although it is clear from the accounts of Captain James Cook and other early European explorers that Polynesians made extensive use of directional stars for navigation. There is, however, a suggestion that a navigational device in the form of a large hollowed-out gourd was used in Polynesia. The "sacred calabash" was carried in the canoe for use as a horizon compass or a sort of sextant for determining latitude. This interpretation has been hotly contested, but there is certainly evidence of the use of *navigation gourds* in the Hawaiian islands after European contact. In addition, at least one Hawaiian account recorded in the nineteenth century suggests that large gourds were used, back on land, as visual aids for teaching about the skies.

See also:

Navigation in Ancient Oceania.

Azimuth; Celestial Sphere; Star Rising and Setting Positions.

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Star Names

Individual stars and groups of stars have different names in different cultures, but in order to speak of these we need to identify them unambiguously using reference names acceptable to everyone. It makes sense to follow the nomenclature used by modern astronomers.

Many stars have generally agreed upon proper names, such as Sirius, Arcturus, Vega, Rigel, and Betelgeuse. However, just as the world is divided into countries, so the sky is now divided up into strictly defined regions—*modern constellations*. This means that all stars, whether named or not, belong to a modern constellation. The convention is to label the most prominent stars in each constellation, usually in order of brightness but sometimes according to their position, using the Greek letters—α (alpha), β (beta), γ (gamma), δ (delta), ε (epsilon), ζ (zeta), and so on—combined with the constellation name (actually the Latin genitive): thus Sirius, the brightest star in Canis Major, is α Canis Majoris. One example best known by its name in this form is α Centauri.

Each constellation also has a three-letter abbreviation, for example Dra for Draco(nis), CMa for Canis Major(is), and Ori for Orion. Thus Betelgeuse is α Ori, Rigel is β Ori, and Sirius is α CMa. Other conventions hold for fainter stars but are generally of no relevance to archaeoastronomy or ethnoastronomy.

See also:
Archaeoastronomy; Ethnoastronomy; Orion.

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Star of Bethlehem

According to the Christian scriptures—specifically, the Gospel of St. Matthew—wise men from the east arrived in Jerusalem to worship the King of the Jews, declaring that they had seen his star in the east. As they journeyed southward to Bethlehem the star went before them until it stopped over the place where the child was. Ever since the third century, scholars have struggled to find a concrete explanation for what has become known as the Star of Bethlehem. Twentieth-century efforts are reflected in scores of books and literally hundreds of articles in academic journals.

Although translations differ, one reading of Matthew's account, assuming that it does indeed have its basis in observed fact, interprets "star in the east" as "star at its rising." We must then assume that the journey to

Bethlehem was made when the star was high in the sky ahead of the Magi, to the south. Clearly it could not have stopped dead in the sky, so "stopped over" is then taken to mean "set behind."

Several types of spectacular astronomical phenomena have been identified as leading candidates. The historical context, which fixes the date of Christ's birth to around 6 B.C.E., provides a strong constraint. On the assumption that the Star of Bethlehem was literally a star, but an unfamiliar one that suddenly appeared in the sky at the time, an obvious possibility is a nova or supernova. The latter is a dying star that gains hugely in brightness for a short period, typically just a few weeks. Some supernovae are even visible by day, so we would not be forced to speculate that the Magi traveled by night. Unfortunately, if a supernova had occurred at the time we would expect Chinese astronomers to have recorded a "guest star." They did not, unless one counts a "tailed object," more probably a comet, seen in the spring of 5 B.C.E. Another possibility is a conjunction (close coming together) of two planets, each themselves among the brightest objects in the sky. In the summer and autumn of 7 B.C.E., the planets Jupiter and Saturn passed each other three times. Nonetheless, eye-catching as this would have been, they would still have been seen as two "stars" and would only have led the way at night. Some have argued that it was the succession of several rather unusual astronomical phenomena that augured great events, but this stretches credulity even further.

A serious weakness in all of these arguments is that they fail to take account of the Magi's own worldview. The Magi were astrologers, probably from Persia. We know that astrological prognostications of the time derived from a complex set of interrelationships between the planets and the zodiacal constellations they appeared in. We also know that each constellation had terrestrial associations, and that Aries or Pisces was associated with Judaea. American astronomer Michael Molnar has recently argued from this standpoint that an occultation of the planet Jupiter by the moon (in other words, the moon passing directly in front of the planet) that occurred in the constellation of Aries in the spring of 6 B.C.E. was an astrological portent of enormous significance and pointed directly to the birth of a new king in Judaea. In Molnar's reading, Matthew's "rising in the east" refers to a planetary heliacal rising, and "stopping" to retrograde motion. Aspects of this interpretation continue to be strongly debated. Most controversially, the occultation in question would actually have been rendered invisible by the light of the sun. This would not have diminished its astrological significance, but the question remains of whether the astrologers of the time would have been able to calculate it.

Be this as it may, it seems obvious in retrospect that the solution to the Star of Bethlehem mystery lies not in events that would be considered conspicuous by modern astronomers but in events that would have stood out in terms of the horoscopes generated by the astrologers of the time.

See also:
Astrology.
Babylonian Astronomy and Astrology.
Superior Planets, Motions of.

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Star Rising and Setting Positions

Any given star, viewed from a given place, traces the same path across the celestial dome night after night. Though it always rises and sets in the same place, the time of day when these two events occur alters constantly, getting earlier by about four minutes each night. Each of them will occur during daylight for about half of the year, and hence be invisible. So also will all or part of the star's daily passage across the sky, whenever the sun is in the sky at the same time. When people in the past observed the rising of certain stars and aligned sacred structures upon them, the event of particular significance was often the heliacal rise, the annual event when the star first rose sufficiently long before the sun to become visible in the predawn sky.

Observations of the rising and setting of stars are especially useful to the navigator wishing to set or maintain a course. Micronesian and Polynesian navigators, for example, had an excellent knowledge of the stars associated with various directions, and this served them well during their long voyages across the Pacific. In practice, such observations are hampered by extinction, the dimming of a star's light due to absorption in the intervening atmosphere. This problem is most severe when a star is close to the sea horizon because its light has had to travel through a great deal more of the earth's atmosphere before it reaches the observer than when it is higher in the sky. This is a potential headache for the navigator, as all but the brightest stars may need to be considerably above the horizon to be visible at all. However, it is less of a problem close to the equator, where the celestial bodies rise and set almost vertically.

Over a long timescale, the slow tumbling of the whole celestial sphere due to precession gradually causes the rising and setting positions of stars to drift. As a result, the place on the horizon where a star rises or sets in the present day may be several degrees away from where it rose or set at the time of interest (for example when a monumental alignment was built) several centuries or more in the past. Some stars that (for locations in the northern hemisphere) rise and set close to due south (or close to due north in the southern hemisphere) may not have appeared above the horizon at all at certain times in the past, while others visible then may since have disappeared.

Precession limits our confidence when we try to identify putative stellar alignments at ancient monuments, since there is invariably some (and often considerable) uncertainty about the date of construction and use. Extinction adds a further complication to the interpretation of such alignments, especially at high latitudes where stars rise and set at a considerable angle to the vertical, since it is difficult to be sure about exactly where a given star was when it appeared or disappeared.

See also:

Astronomical Dating; Methodology; Navigation.

Star Compasses of the Pacific.

Celestial Sphere; Declination; Extinction; Heliacal Rise; How the Sky Has Changed over the Centuries; Precession.

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Statistical Analysis

The need for statistical analysis arises in archaeoastronomy because astronomical patterns we perceive in the archaeological record may have come about purely by chance, or to be more precise, as a result of factors quite unrelated to astronomy. Doubts about intentionality can apply to a whole range of types of evidence concerning ancient astronomy: monuments aligned upon the rising and setting positions of astronomical bodies; displays of sunlight and shadow only visible on rare occasions; groups of monuments placed so that their positions on the ground mimic the shape of a constellation; patterns of tally marks carved on rocks or portable artifacts that include could have functioned as calendars; and so on.

In the formative days of archaeoastronomy in the 1960s to 1980s, statistical analysis was most extensively applied in assessing monumental alignments. Indeed, this approach came to characterize the "green," or European, approach to archaeoastronomy, which focused on prehistoric monuments without the benefit of related historical or written evidence. Broadly speaking, the approach taken was that pioneered by the Scottish engineer Alexander Thom, which was to accumulate data from many alignments and determine the declination of the horizon point "indicated" by each alignment, and then to use statistical methods to determine whether observed declination "peaks"—repeated occurrences of particular declinations—were in fact significant. If so, then a consistent astronomical purpose was evident and the question could be asked, which astronomical body the given declination might have corresponded to.

Devising a suitable statistical test is by no means straightforward. Sometimes one can only resort to *Monte-Carlo testing,* a method by which one generates, for example, randomly oriented sets of monuments in the computer and sees in what proportion of cases they contain at least as many of a particular type of alignment as were found in the "real" data. If the answer is, say, only once in every thousand runs, then one can conclude that the chances of the real data having arisen fortuitously are only one in a thousand; as this probability is so small, it is fair to conclude that the alignments were deliberately intended. However, there are a number of dangers and pitfalls with this method. An obvious one is that the data must be fairly selected. Even leaving out one site simply because it seems to be pointing in a different direction from all the rest (and it is often easy enough to find retrospective reasons for doing this) can badly distort the results and so undermine any statistical conclusions.

A less obvious but more fundamental difficulty relates to the whole nature of hypothesis testing in this way. Many statistical procedures assume that the hypothesis preceded the data, whereas in an archaeological context, a particular interpretation is generally first suggested by the data (or most of it), since archaeologists do not have the opportunity for repeated experiments. The hypothesis that we choose to test may itself be selected from innumerable possibilities. To take an example, it is a well-known though astonishing fact that if twenty-three people are selected randomly, there is an even chance that two of them will have the same birthday. However, if we took such a group, observed that two of them had birthdays (say) on July 27, and on the basis of that chose to assess the chances (test the hypothesis) that two July 27 birthdays could have arisen among the group purely fortuitously, we would obtain the result "highly unlikely." The reason, of course, is that we chose to test the "July 27" hypothesis (rather than any one of 364 others) because the data contained that pattern in the first place. In short, statistical methods must be used with considerable care, especially where they purport to assign *significance levels* to particular results.

Nowadays there is a much greater reliance on simply displaying the data. If certain trends are strong enough, then their intentionality is obvious, as is the case for the orientations of numerous local groups of later prehistoric tombs and temples in western Europe. Where we need to assess sets of measured declinations, Alexander Thom's method of *curvigrams*—graphs showing accumulations of probability—seems as good a method of visualizing the likely significance of repeatedly occurring declinations as any. The fair selection of data remains a much more crucial issue.

In recent years archaeoastronomers have begun to recognize the potential of a rather different statistical approach: the *Bayesian paradigm*. This approach allows one to assess data repeatedly against different "prior" ideas and to take into account background information. It is especially useful where we are trying to integrate different types of evidence, such as historical records.

However, we must look beyond statistical analysis if we wish to do more than establish the intentionality of astronomical alignments or other astronomically related patterns evident in the archaeological record. No amount of statistical analysis can help with the interpretation of their significance and meaning to the people who built and used them.

See also:

Alignment Studies; Constellation Maps on the Ground; "Green" Archaeoastronomy; Methodology; Orientation; Thom, Alexander (1894–1985).
Prehistoric Tombs and Temples in Europe.
Declination.

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Stone Circles

The stone circle is a type of later prehistoric monument that is commonly found in northwestern Europe but is also found elsewhere in Europe and also in certain other parts of the world. Over 1,300 examples survive in Britain, Ireland, and Brittany, ranging from a few meters to over 350 meters in diameter and containing from five to over thirty standing stones. The stones at some stone circles are mere stumps and rounded boulders; at others they are great monoliths several meters in height.

Stone circles are not always found in isolation. They can be found surrounding tombs, as at Newgrange, or within the banks and ditches of henges, as at Avebury; they can also be connected to lines or avenues of stones, as at Callanish and Beaghmore. Some of the most complex arrangements of several circles and stone alignments are the stone monuments of

One of a complex of Bronze Age stone circles and rows at Aughlish, County Derry, Northern Ireland. (Courtesy of Clive Ruggles)

mid-Ulster. The designs of individual circles are also quite diverse, with a number of regional variants. One of the most distinctive of these is the recumbent stone circle, where one stone is placed on its side. Others include stone circles with entrances, circles with outlying standing stones, embanked circles, and "circles" with distinctive shapes such as ellipses or flattened circles. (Since many are nowhere near true circles, some have suggested that stone circles should more correctly be called "stone rings.")

It is difficult to date a stone circle, but most northwest European examples are thought to have been built in the Later Neolithic or earlier part of the Bronze Age, broadly in the third and second millennia B.C.E. Stones were sometimes transported several kilometers to the site; famously (although exceptionally) the Stonehenge bluestones, weighing up to four tons each, were transported over sea and land some three hundred kilometers (two hundred miles) from the Preseli mountains in southwest Wales.

The purpose of stone circles has long been a mystery. Only a minority are directly associated with tombs. Cists containing small burials are found in some of them, but these are often late additions, perhaps placed at what was already an ancient hallowed or ancestral place whose original purpose was long forgotten. Other than this, archaeological excavations tend to find little in the way of stratigraphy and artifacts, so that for many years stone circles were largely ignored by archaeologists—so much so that the British archaeologist Aubrey Burl once referred to them as the "*personae non gratae* of British prehistory" (Ruggles 2002, p. 176). Yet an obvious assumption—as for any open ring, whether built of earth, timber, or stone—is that they demarcated a piece of special or sacred ground, perhaps a place used for a ceremonial gathering or ritual activity. This means it makes sense to study the form of the rings, their position in the landscape, and their relationship to visible features in the surrounding environment, including objects in the sky. Such investigations are now carried out by archaeologists, but until late in the twentieth century they were the almost exclusive preserve of engineers, astronomers, and others from outside the discipline.

One of the most famous of these was the engineer Alexander Thom, who proposed that many British stone circles were laid out using a standard unit of measurement, the "megalithic yard," of 0.83 meters (2.72 feet). He also claimed that many evidently noncircular rings represent precise geometrical constructions, such as ellipses and various types of "flattened circle," laid out using Pythagorean triangles more than a millennium before they were (re)discovered by Pythagoras. Given all this, Thom's other main idea—that many stone circles incorporated remarkably precise alignments upon the rising and setting positions of the sun, moon, and certain stars—seemed less surprising.

However, time has dealt harshly with the specifics of "megalithic mensuration," "megalithic geometry," and "megalithic astronomy," even though Thom himself is remembered as an important pioneer in getting people to think about such issues. Statistical reappraisals of the diameters of stone circles, given the large size of the stones and their often poor state of preservation, only gives marginal support for the notion that some common unit (perhaps related to the average human pace) was used in setting out many of them; there is no sustainable evidence whatsoever for the idea of a precise measuring stick being carried the length and breadth of later prehistoric Britain. Similarly, the observed shapes of stone circles can all be adequately explained by the use of simpler construction techniques: there is no need to resort to Thom's geometrical constructions. Some have even argued that these monuments may all simply be poor attempts at circles, or that the precise shape didn't matter and was simply laid out by eye.

A major problem with studying possible astronomical alignments at stone circles is the number of different ways in which such an alignment might have been set up: in the direction of the entrance where one exists; in the direction of the tallest stone; from the circle center to an outlier where one exists, or vice versa; (either way) along the main axis where one can be identified (e.g., in the case of an elliptical ring); (either way) between the tallest stones; and so on. At many stone circles, many potential alignments of various types may exist, making it quite likely—even, in some cases, highly probable—that one or more of them will align purely by chance upon a prominent feature in the landscape or a major celestial body or event. This means that in order to have some degree of confidence that any alignment we spot was actually intentional and meaningful, we have to pay particular attention to questions of methodology.

In just a few types of stone circle, one direction of alignment stands out from any others as possibly significant. Where this occurs we find some of the strongest evidence of an intense interest in the sun and/or moon, although not consistently. In this context the Scottish recumbent stone circles and the Irish axial stone circles are particularly important. However, as with mensuration and geometry, the high precision astronomical alignments envisaged by Thom have not withstood the test of time. They simply cannot be convincingly demonstrated on the basis of the evidence available. Though absence of evidence is not evidence of absence, until and unless such evidence emerges, we have no need to fit chiefs, shamans, or priests obsessed with the minutiae of the moon's motions over several generations into our models of later prehistoric societies in Britain and Ireland.

On the other hand, solar and lunar alignments of less than pinpoint accuracy are nonetheless highly fascinating. They suggest, for example, that circles may have become charged with meaning at certain times, when the celestial bodies reached particular configurations in relation to the stones of the circle. At some sites, other forms of archaeological evidence reinforce the idea of ceremonies taking place when the celestial configuration was right. A good example of this is the scatters of moon-reflecting white stones such as quartz that are found around the base of the recumbent stone at some Scottish recumbent stone circles, reinforcing the idea that ceremonies took place here by the light of the full moon on a midsummer evening when it appeared low over the recumbent stone. Such ideas must be considered in the broader context of cosmological ideas that could have viewed these monuments as microcosms or placed them conceptually at the very center of the world.

See also:

Methodology; Palaeoscience; Thom, Alexander (1894–1985).

Avebury; Axial Stone Circles; Callanish; Circles of Earth, Timber, and Stone; Megalithic Monuments of Britain and Ireland; Newgrange; Recumbent Stone Circles; Stonehenge.

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Stonehenge

Stonehenge, one of the most famous archaeological sites in the world, has long been associated with astronomy. Situated on the chalk uplands of the Wessex region in southern England, in the county of Wiltshire, the monument is characterized by its huge sarsen stones, some of which stand over seven meters (twenty-two feet) tall. The tallest are the remains of five *trilithons* (two uprights with a horizontal *lintel* placed across their tops) arranged in the shape of a horseshoe, and these are surrounded by what was once a continuous ring of only slightly less tall uprights and lintels. Almost unimaginably, these huge stones, weighing up to forty tons apiece, were dragged here, down- and uphill, over a distance of some thirty kilometers (eighteen miles) from the Marlborough Downs to the north. Where the stones have collapsed it is possible to see some of the carefully carved mortice-and-tenon and tongue-and-groove joints (joints that would normally be associated with woodworking) that were used to hold them together. The horseshoe is oriented northeastwards. Looking out in this direction through a well-preserved section of the outer circle of sarsens, one sees a much rougher stone, leaning over and badly weathered. This is the famous Heelstone, which stands some sixty meters outside the outer ring.

The purpose and function of the great stone monument at Stonehenge has been a source of speculation for centuries. That it was a place of great power is self-evident. Regarding astronomy, it has been portrayed variously as a cosmic temple, a calendrical device, an observatory, and an eclipse calculator. Many of these ideas have attracted widespread public interest.

However, the majority of astronomical theories concerning Stonehenge have little hard evidence to support them. Many are based on the idea that, at one stage or another, the monument incorporated deliberate architectural alignments upon the rising and setting positions of celestial bodies, particularly the sun or moon. The problem is that every architectural alignment must point somewhere, and many factors might have influenced any particular orientation. Just because a pair of stones is aligned upon, say, the position of sunrise at one of the solstices, does not mean that this was deliberate or that it meant anything at all to the people who built and used the monument. We must be particularly cautious if we only find a modest number of potential astronomical alignments among a great many possibilities: and there are hundreds of ways of aligning different pairs of stones at Stonehenge.

The view out along the axis of the sarsen monument at Stonehenge, in the direction of midsummer sunrise. The Heelstone is visible in the distance to the right of the axial alignment; another stone, probably similar, once stood symmetrically to the left. (Courtesy of Clive Ruggles)

One of the most famous astronomical speculations about Stonehenge is that it functioned as a calculating device for predicting eclipses. Put forward in the early 1960s in a popular book by Gerald Hawkins entitled *Stonehenge Decoded,* and later elaborated by the astronomer Fred Hoyle, the idea is basically that a small number of wooden posts were moved around the Aubrey Holes according to strictly defined rules (the two authors suggested different methods). When certain configurations were reached, then it was a "danger period" when eclipses could occur.

The Aubrey Holes are a ring of fifty-six pits surrounding the sarsen monument, named after the antiquarian John Aubrey who discovered them in the seventeenth century. Concrete markers mark their positions for the modern visitor. Those who challenged the theory were often asked "why *were* there fifty-six Aubrey Holes, then?" But to try to answer this question is to miss the point. There has to be some number of holes in the ring, even if it was created for some other purpose; and we may never know with any certitude what that purpose was. Some astronomers in the 1960s showed that the number fifty-six is not that special with regard to predicting eclipses: similar post-moving schemes can be devised with other numbers of holes in the circle. Archaeologists know of many similar pit circles in Britain, varying in number from less than twenty to over a hundred. The number fifty-six is not special, then, either archaeologically or astronomically. Finally, to further confound the Hawkins/Hoyle theory, the archaeological evidence shows that at least some of the Aubrey Holes at Stonehenge held permanent timber posts, albeit possibly after being left open for a time.

To be plausible, astronomical theories at Stonehenge must be consistent with what we know of the chronological development of the monument from the many archaeological investigations that have taken place there, particularly during the twentieth century. The great sarsen circle and trilithons, constructed in about 2400 B.C.E., were not the first construction that left its trace at this spot. The smaller bluestones had been brought there all the way from the Preseli mountains in South Wales, a distance of some 300 kilometers (200 miles), perhaps a century earlier. And some four or five centuries earlier still, an earthen enclosure, consisting of a circular ditch and inner bank, was built here, probably broadly contemporary with the Aubrey pits/posts. Yet, more remarkably, the postholes of five huge timber poles, erected several millennia earlier, in about 8000 B.C.E., were discovered during the construction of the Stonehenge parking lot in the 1970s.

During the first half of the third millennium B.C.E., the earthen enclosure seems to have been left to decay. The ditch silted up and the timber posts eventually rotted away, leaving only the Aubrey Holes. People did come, though, and carefully placed offerings such as articulated animal bones and later animal and human cremations, in the ditch and in the Aubrey Holes themselves. The distribution of these offerings around the site is far from haphazard and does seem to have been related to the motions of the sun and moon, perhaps reflecting the cosmological beliefs of the visitors to what may already have been a sacred ancestral site. This recent discovery is important, because it demonstrates that in order to understand better how and why people's activities related to the celestial bodies in the past we must try to look beyond the architecture of monuments. Archaeological excavations, which can reveal evidence of ritualistic activities that have no apparent "rational" explanation in our terms, may give us some important insights.

When stones were first brought to Stonehenge, its axis was changed. It was now aligned in the northeast upon midsummer sunrise. In other words, at dawn on the longest day of the year (and for some days before and after) the sun would have risen squarely between the Heelstone and a companion that has since disappeared, a beam of light shining along a corridor of stones and into the interior of the sarsen ring. The axis was also aligned, in the opposite direction, upon sunset on the shortest day. It is likely that this was the real focus of the monument, since the ceremonial approach was along an avenue from the northeast, so that people would have approached facing the southwest.

Modern druids participating in a ceremony at Stonehenge, England, on the morning of the summer solstice in 1976. (Courtesy of Clive Ruggles)

Among many other astronomical alignments claimed at Stonehenge, one of the most intriguing concerns the four *station stones.* Two of these remain in situ, just inside the ditch where the timber circle once stood. They appear to be broadly contemporary with the first appearance of other stones at the site (though this is unconfirmed archaeologically) and formed a rectangle. The lengths of its sides are in the ratio 5:12, a fact that has led some people to speculate that the builders had knowledge of Pythagorean geometry, since this ratio gives a diagonal whose length is a whole number (thirteen) of the same units. The shorter sides of the rectangle are aligned along the main axis of the monument, on midsummer sunrise and midwinter sunset, while its longer sides are aligned toward the southeast upon a point close to the most southerly rising point of the moon. This alignment has led to claims that the latitude of Stonehenge was carefully chosen to optimize this arrangement. However, such an argument is flawed on a number of grounds, most obviously because the earlier monument had already existed on this spot for several centuries. In any case, the optimal latitude would actually be well to the south, somewhere in the English Channel.

In comparison, there is little doubt that the solstitial alignment of the main axis of Stonehenge in its later phases was intentional. Its purpose may have been as a display of power, showing that this monument, erected with a huge input of human labor from exotic materials (stone brought from great distances), was in harmony with nature. Its power would reinforce the power of those who were seen to be in control of it. Certainly by the middle of the third millennium B.C.E., Wessex cheftains were powerful and commanded great long-distance exchange networks. During the ensuing millennium, dozens of rich and powerful chieftains were buried along with their personal treasures in round barrows within sight of Stonehenge, relating in some way to the power of this great ancestral monument.

See also:

Cosmology; Lunar Eclipses; Solar Eclipses; Solstitial Alignments.

Bush Barrow Gold Lozenge; Crucuno; Megalithic Monuments of Britain and Ireland.

Moon, Motions of; Solstices.

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Sun, Motions of

On any particular day of the year, the sun occupies a certain position among the stars. As the celestial sphere turns in the course of its daily (diurnal) rotation, the sun—like all the stars—appears to trace out a line of constant "latitude" (for which the technical term is *declination*) on that rotating sphere. Unlike the stars, though, during the course of a year—as the sun moves gradually along its annual path through the stars, known as the *ecliptic*—its declination changes. It is at its farthest north at the June solstice, when its declination is about +23.5 degrees, corresponding to the latitude of the Tropic of Cancer on the earth. Conversely, it is at its farthest south at the December solstice, when its declination is about –23.5 degrees, corresponding to the terrestrial latitude of the Tropic of Capricorn. Over the years its declination varies continuously between these limits in a smooth, wave-like manner. In the same way, its rising position moves continually to and fro along the eastern horizon, reaching its limits at the solstices; and the same is true of its setting position in the west.

If we have an alignment that we suspect relates to the rising or setting position of the sun, then we only have to determine the declination of the relevant point on the horizon in order to deduce when in the year the sun will rise or set there. There are always two such times: one when the sun is moving north (in the northern hemisphere spring or southern hemisphere autumn) and the other when it is moving south. There will be a slight uncertainty of up to a day in each case, mainly because of the leap-year cycle. It is convenient to express the resulting dates in terms of the modern Gregorian calendar, but when we interpret our alignments, we must bear in mind that the people who set them up would have used different calendars. For example, when medieval churches were constructed, the Julian calendar was in use. The other complication is that if we delve deeply into the past, we must make a slight correction (only normally significant on a time scale of millennia) to take into account an effect known as the change in the obliquity of the ecliptic.

See also:

Church Orientations; Gregorian Calendar; Julian Calendar; "Megalithic" Calendar; Solstitial Directions.

Celestial Sphere; Declination; Diurnal Motion; Ecliptic; Obliquity of the Ecliptic; Solstices.

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Superior Planets, Motions of

The planets Mars, Jupiter, and Saturn revolve around the sun on orbits outside that of Earth. As a result, they travel round the sun more slowly. Suppose for a moment that the earth simply vanished, leaving a sentient space monster orbiting the sun in its place, its head upward to the north. For want of anything better to do, the monster decides to ignore everything else in the sky but the sun and Mars, keeping its face toward the sun and watching Mars gradually progressing around it. At intervals it sees Mars pass slowly by the sun on the far side (only rarely will it pass directly behind it): this is known as *conjunction.* Mars is actually traveling to the monster's left, but the monster is traveling faster and in the opposite direction, so Mars appears to emerge from behind the sun traveling right. As Mars continues its journey round the sun, its angle rightward from the sun steadily increases, slowly at first, but more rapidly as the monster catches it up. Eventually, it passes round behind the monster, an event known as *opposition,* and the sequence is then repeated in reverse on the monster's left until Mars eventually approaches the sun again from the left prior to another conjunction.

The sequence of events for an Earth-based observer reflects those just described, except that we view them from the surface of a spinning planet.

An observer in the northern hemisphere perceives the celestial sphere to be turning to the right. If Mars is to the right of the sun, it rises earlier, passes across the sky to the right (west) of the sun, and sets earlier. The directions are reversed for an observer in the southern hemisphere, whose perceptions can be modeled by turning the space monster upside-down.

About sixty days after conjunction, then, Mars appears in the eastern sky before sunrise. This event is known as the *heliacal rise*—a similar concept to the heliacal rise of stars. As it gradually draws away westward from the sun, it rises earlier and climbs higher in the sky by sunrise. It also increases in brightness as it comes closer. The changes become more rapid as the planet approaches opposition, when it is at its closest and brightest. At this time, it rises at about sunset and can be seen in the sky all night before setting at about sunrise. The sequence is now repeated in reverse and in mirror image. The planet increases in distance and decreases in brightness, rapidly at first. It is now visible only in the evenings and gradually approaches the sun, appearing ever lower in the sky at sunset and setting earlier. Eventually, it ceases to be visible (this is known as its *heliacal setting*). This is followed by another conjunction, and the cycle is repeated.

Returning to the monster for a moment, suppose that it turns its attention to the apparent motion of Mars against the background stars. Suppose that it now keeps its face toward Mars, watching it pass steadily leftward (eastward) through the stars as the weeks and months go past. It probably expects this to be fairly uneventful, but it is in for a surprise. As it approaches opposition, Mars appears to stop and go into reverse. (Actually, it does not stop, because there is a slight up-and-down motion as well, so that the path traced out against the stars is a U-shape or loop.) At opposition, it appears to be going backward (westward), but then, some days later, it stops a second time and resumes its forward (eastward) progress. This phenomenon is known as *retrograde motion*. Around the time Earth is overtaking Mars, it is traveling faster than Mars in roughly the same direction, so Mars must appear to be moving backward relative to the distant stars. At other times the two planets are heading in very different directions, so the component of the earth's motion in the same direction as Mars is either much smaller or, for much of the time, in the opposite direction. This means that Mars will still appear to be moving forward in relation to the distant backdrop of stars.

The period between successive occurrences of the same configuration (the *synodic period*) of Mars is 780 days. Invisibility around conjunction lasts for about 120 days, and retrograde motion around opposition for about 75 days (with wide variations). Jupiter and Saturn, being much farther from the sun, progress much more slowly around their orbits, taking several years to complete even one circuit. This means that their synodic periods are shorter, since these are mainly determined by the rate of the earth's rotation around the sun. However, the essential characteristics of their motions are the same as for Mars. The synodic period of Jupiter is 399 days, disappearance around conjunction lasts for about 32, and retrograde motion for around 120. For Saturn the respective figures are 378, 25, and 140 days.

Retrograde motion was an enigma to pre-Copernican astronomers. Some of their solutions—such as the Greek epicycles—were extremely elegant, but they were ultimately doomed to failure.

See also:
Dresden Codex; Star of Bethlehem.
Celestial Sphere; Heliacal Rise; Inferior Planets, Motions of.

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Supernovae

See Comets, Novae, and Meteors.

Surveying

See Field Survey.

Swedish Rock Art

Scattered among the fertile plains of central and southern Sweden, and found on boulders, outcrops, and flat rock surfaces, are a remarkable quantity of prehistoric rock carvings. Mostly attributed to the Bronze Age, and thus dating to the second and the early part of the first millennia B.C.E., they include depictions of people, boats, horses, and other animals; wagons and wheels; the soles of feet, resembling footprints, either barefoot or wearing sandals; and more abstract elements such as spirals, discs, and cup marks. Particularly impressive are those sites where we find combinations or accumulations of scores, or even hundreds, of rock carvings in a single place. One small area to the northwest of Stockholm, covering just nine parishes, was studied recently by British archaeologist John Coles. It alone was found to contain 840 rock art sites containing over 1,500 boats, 350 people and animals, and 300 soles of feet, together with around 19,000 cup marks.

Some Swedish rock carvings have been interpreted as representations of ancient constellations and calendars, along with depictions of spectacular events such as comets, supernovae, and eclipses. These ideas, developed in great detail during the 1980s and early 1990s by the Swedish astronomer Göran Henriksson, received a good deal of publicity within Sweden, but also proved controversial and even contentious. The main criticism leveled at them was that they were highly subjective. Attributing meaning to rock art, where there are no "informants" to give us any sort of clue, is notoriously difficult—many would say impossible—since meaning is highly dependent upon cultural context. Archaeologists, for this reason, normally tend to limit themselves to formal analyses of the frequency of certain designs, the location of rock art sites in the landscape, and similar questions, and to broad interpretations relating to the cultural setting and to ancient perceptions of the environment. Attributing specific meaning to particular carvings is unavoidably speculative and especially dangerous, since there is very wide scope for fitting complex explanations to complex data.

A particular scene found on a rock panel at Ekenburg near the town of Norrköping, about 140 kilometers (90 miles) southwest of Stockholm, has been claimed to depict the sky as seen during a total solar eclipse. The event in question took place in 1596 B.C.E. For just under three minutes, as the sun was covered by the moon, people would have seen four bright planets and a spectacular comet—Comet Encke—close to it in the daytime sky. A set of concentric rings with a dagger-like object sticking into one side is interpreted as the eclipsed sun with the tail of Comet Encke adjacent to it. Four nearby cup marks are interpreted as the planets, and a nearby boat is interpreted as a constellation comprising parts of Gemini and Taurus.

Attractive as it might seem, there are a number of problems with this interpretation. For one thing, some astronomers dispute the calculation of the time of the eclipse, which depends on certain assumptions about the slowing of the rate of rotation of the earth. Others point out that the orbit of Encke's Comet cannot be calculated prior to C.E. 1100 owing to a close encounter with Jupiter. In any case, the attribution of this particular astronomical event is speculative; the choice of which carvings are included while other adjacent ones are dismissed as not part of the eclipse scene is arbitrary (and influenced by the interpretation being put forward); and the goodness of fit—in other words, the positions of (for example) the cup marks compared with the positions of the actual planets in the sky at the time—is not good.

The lesson to be learned here is a methodological one. Enthusiasm in fitting an astronomical explanation to an archaeological phenomenon is no substitute for fairly assessing the data. Fitting a complex astronomical explanation to complex archaeological data brings the danger that any number of different, equally complex theories might fit the data equally well. If this is so, then we cannot claim that the evidence supports our theory in particular. How, then, do we estimate how many other complex explanations could have fit equally well? This is not an easy question to answer and not always of immediate interest to those who see that the data appear to fit their favored theory well enough; but a scientific approach demands that we be prepared to consider this question, and that we make a serious attempt to assess it fairly.

See also:

Comets, Novae, and Meteors; Eclipse Records and the Earth's Rotation; Methodology; Solar Eclipses.

Presa de la Mula.

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Symbols

Many archaeologists now believe that it is possible to reconstruct elements of human cognition from material remains. But in order to do so, it is crucial to recognize a means of expression unique to human beings: the use of symbols. The digit "2," for example, is a symbol used by Europeans to define a certain numerical concept. But if a hypothetical future archaeologist, ignorant of all other aspects of twentieth-century European culture, were to try to interpret the digit "2" carved, say, on an isolated stone, they could not deduce its meaning from the form of the symbol alone. On the other hand, they might be able to deduce something from the fact that stones marked "1 km," "2 km," "3 km," etc. occurred at intervals a fixed distance apart by the side of a road. The context of the symbols—their association with one another, as well as their association with the road, which seems relevant to the way in which they were used, and their spatial distribution—clearly does suggest possible meanings. A complication is that symbols may mean several different things at once; they may convey different meanings to different people, some of which may be very different from those intended; and the meanings may well change through time. But just as the Stars and Stripes would be recognized by virtually everyone in the modern world as a symbol of the United States, people sharing a common cultural background are likely to perceive common sets of meanings. It is this set of shared meanings that gives us some hope of retrieving meanings that reflect certain worldviews.

Designs found in prehistoric rock art, especially those that do not obviously "literally" represent something like an animal, may have had symbolic meaning, and it is possible to try to deduce something about that meaning from its context. For example, it has been suggested that many circles and rayed circles in megalithic art all round the Atlantic fringe of Europe may be sun symbols or representations. Such a design, along with other decorations, was carved onto the back corbel of the roof-box above the entrance of the Neolithic passage tomb at Newgrange, Ireland. The tomb was apparently designed so that shortly after sunrise on days around winter solstice, the sun would shine through the roof-box and down the nineteen-meter-long passage, reaching the chambers in the interior of the tomb.

Can we do more than simply recognize possible symbols and possible meanings? Can we use them to reconstruct elements of other worldviews? What gives us hope is the human propensity to express and reinforce the nature of the cosmos, as a given group of people perceives it, in many different ways in order to keep their own lives and activities in harmony with the world. Verbal or visual metaphors might be expressed in myth, exhibited in activities that we might interpret as either ritualistic or mundane (or both), or displayed in architecture. For example, hogans, traditional round or octagonal buildings built by Navajo families in the southwestern United States, reflect the harmony of the cosmos in various ways. Their single door faces the rising sun, and the space within is conceptually divided into four quarters used in different ways, reflecting the four directions of the cosmos and their associated properties and qualities. Movement within the hogan is always clockwise, reflecting the motion of the sun around the sky.

Where we have only the material record to go by, associations between symbols, if we can fathom their meaning, may give us insights into correspondences that form part of a worldview. We might notice, for example, the consistent orientation of hogans toward the solar rising arc in the east; if in addition we consistently found material evidence of different activities in the four quarters of the hogan, we might correctly deduce the quadripartite structure of the Navajo cosmos.

See also:

Cognitive Archaeology; Cosmology; Science or Symbolism?; Star and Crescent Symbol.

Mesoamerican Cross-Circle Designs; Navajo Hogan; Newgrange.

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Synodic Month

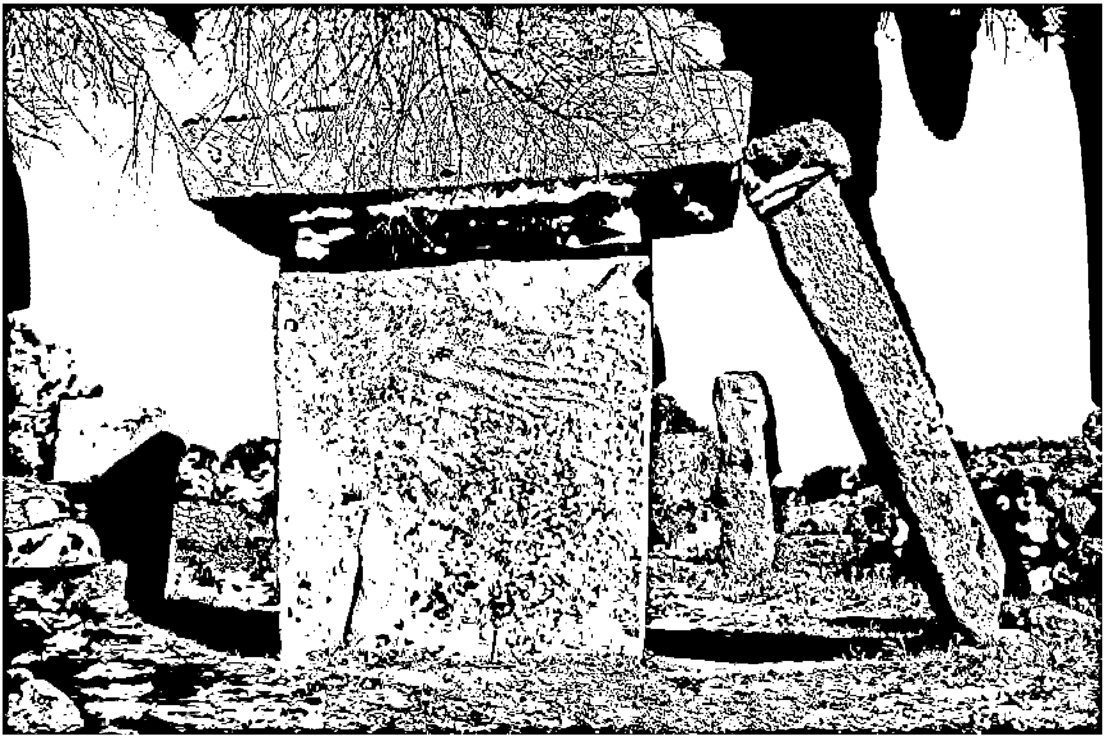
See Lunar Phase Cycle.

T

Taulas

Taulas are a distinctive type of later prehistoric monument found exclusively on the Mediterranean island of Menorca. Attributed to the talayotic culture—so called because it is characterized by a type of dry-stone tower known as a *talayot*—they date broadly to the late second and early first millennia B.C.E. Taulas consist of two large rectangular blocks of stone, one standing upright and the other placed across the top, balanced centrally, so as to form a shape resembling the letter "T." These were placed within stone-walled precincts. One side of the "T" was worked flat and smooth. This side faced the visitors as they came in through the single entrance, as well as the wider landscape beyond. Each major village seems to have had its taula, and some twenty-five examples are known, in various states of preservation, scattered about the small island.

The orientations of taulas (and the precinct entrances) are not random; they face generally southwards, within a range from southeast to south-southwest. In every case there is an uninterrupted view out to a distant horizon, suggesting that it was important to have a clear view of the sky in that direction. Yet this direction does not correspond to that of the rising or setting position of the sun, moon, or planets, leaving only the possibility that the taulas were aligned on certain stars. It is possible that the asterism of interest was the Southern Cross and Pointers, a very conspicuous group of bright stars appearing low in the southern sky at this latitude in the second millennium B.C.E. This might also explain the puzzling fact that no taulas are found on neighboring Mallorca, despite the fact that talayots are equally abundant there. Mallorca, unlike Menorca, is mountainous and the landscape around the principal Mallorcan villages (concentrated in the fertile northern part of the island) would not have permitted a clear view of the southern sky. In other words, people living on Mallorca had no possibility of seeing the Southern Cross and so did not build taulas. However, if the Menorcan taulas were indeed linked inextricably with the Southern Cross and Pointers, then the passage of time would have presented the ancient



The taula at Talatí de Dalt, Menorca, viewed from the entrance of its enclosure. Leaning against it is a pillar, with a small capstone of its own, which incredibly became wedged when it fell from the vertical. (Courtesy of Clive Ruggles)

Menorcans with a problem. Owing to precession, these stars dropped lower and lower in the southern skies as the centuries progressed, until by the onset of the first millennium B.C.E. they were hardly visible at all.

Taulas certainly had sacred associations, as is clear from broken statues and sacrificed animal bones strewn about the precincts. In one case these included a statue of the Egyptian god of medicine, Imhotep, complete with a hieroglyphic inscription; at another, excavations uncovered a hoof from a bronze statue, evidently of a horse (or centaur), the remainder presumably having been plundered. Since there is no other evidence of local horse gods, this again suggests links with the eastern Mediterranean. In ancient Egypt, it was common to associate gods and goddesses with stars and constellations, and in Greek mythology the god of medicine, Asclepius (counterpart to the Egyptian Imhotep), was tutored by a centaur—Chiron. Tentatively weaving together these threads, the British historian of astronomy Michael Hoskin suggested that the taula sanctuaries may have been places of healing and were oriented upon the constellation of the centaur—Centaurus. The Southern Cross and Pointers are at the feet of the centaur in the sky, the Pointers (α and β Centauri) forming the two brightest stars of the modern constellation.

See also:
Son Mas.
Precession.

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Temple Alignments in Ancient Greece

The first systematic study of temple orientations in ancient Greece was carried out by Heinrich Nissen in the nineteenth century. William Dinsmoor, carrying out another study in the 1930s, concluded that almost three quarters (73 percent) of them were oriented eastward within the range of sunrise. Some were oriented on sunrise on the feast day of the deity to whom the temple was dedicated. One example is the Parthenon itself, dedicated to Athena. It is not only aligned upon the sunrise on the feast day of Athena but also upon a prominent hill—Mount Hymettos. How widespread or long-lasting this practice was is a hard question to answer. The evidence is complicated by the fact that many temples were reconstructed on a different orientation or their dedication was changed. Historical sources also make it clear that sunrise was not always the principal concern. The Greek writer Vitruvius, in his work *De Architectura,* indicates that there was sometimes a preference for facing nearby cities or directions of approach along rivers or roads.

It has been suggested that the predominantly easterly orientation of Greek temples may reflect broader orientation practices extending back as far as the Bronze Age. The Minoan culture survived on the island of Crete until the middle of the second millennium B.C.E., after which the Mycenaeans from the Greek mainland took control. Elements of both Mycenaean and Minoan orientation practices may have come to influence Archaic and, in due course, Classical Greek temples, but the practice of easterly orientation seems to derive from the Minoans. Studies of the orientations of over three

The Temple of Poseidon at Sounio, Greece, viewed toward the entrance. Like many such temples it faces within a few degrees of east. (Courtesy of Clive Ruggles)

hundred Bronze Age passage tombs on Crete, dating back to the mid-third millennium B.C.E., show a very strong easterly trend, with over 80 percent of them lying within the solar arc. An even higher proportion (about 87 percent) are within the slightly wider lunar arc. Over half the data are derived from a single cemetery, Armenoi in western Crete. Each of the more than two hundred tombs there is oriented within the range of moonrise; and it is surely not coincidental that three kilometers (two miles) to the east is Mount Vrysinas, upon whose summit was a peak sanctuary apparently, although not certainly, dedicated to a moon goddess.

The development of mathematical astronomy in ancient Greece from around 400 B.C.E. onward seems to have derived in large part from ancient Babylonia. However, in constructing large stone temples as far back as the seventh century B.C.E., the ancient Greeks acquired both inspiration and technological expertise from ancient Egypt. This linkage opens up the possibility that some of the more symbolic aspects of Greek temple construction, such as architectural alignments upon celestial objects, also derived from ancient Egypt, where there is cultural continuity stretching back into the third millennium B.C.E. Studying the common aspects of astronomical symbolism incorporated in Greek and Egyptian temples may throw more light on this possibility in the future.

See also:

Hesiod (Eighth Century B.C.E.); Nissen, Heinrich (1839–1912).
Egyptian Temples and Tombs; Minoan Temples and Tombs.
Moon, Motions of.

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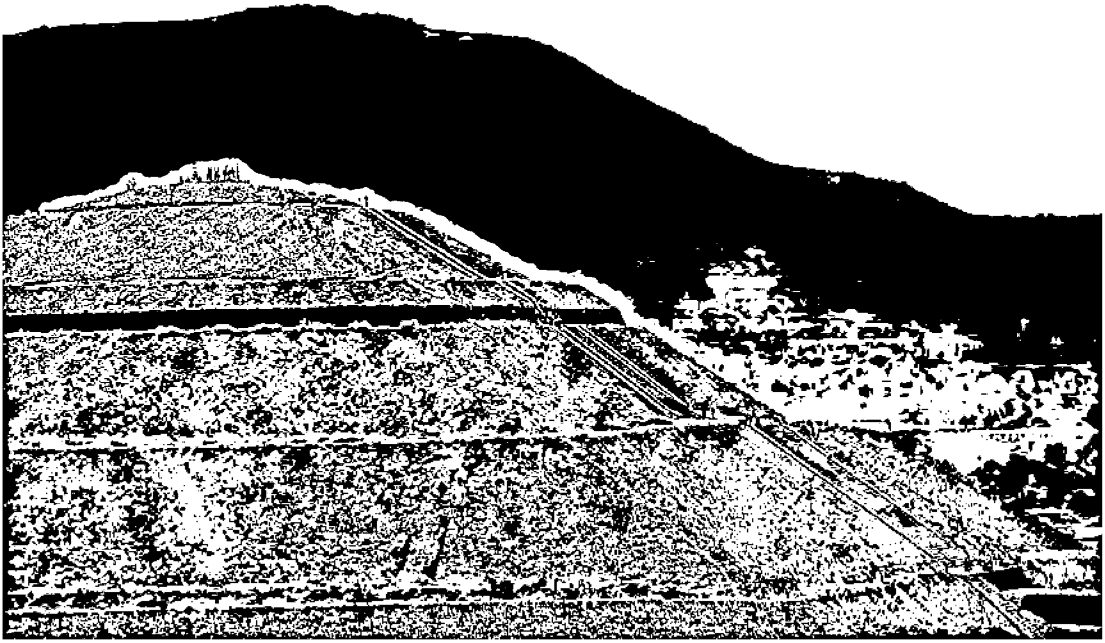
Teotihuacan Street Grid

Teotihuacan was the first pre-industrial city in the New World. Rising to prominence in about 100 B.C.E., it subsequently reached massive proportions, supporting at its height (between about C.E. 350 and 650) a population of around 200,000 and covering some twenty square kilometers (eight square miles). This entire area was partitioned by a regular street grid into about two thousand rectangular "apartment compounds," some containing groups of occupational specialists and others housing different social classes or ethnic groups. Most remarkable of all is the ceremonial center, its wide main street (the so-called Street of the Dead) lined with splendid courtyards, palaces, and temples. It also contained the two great pyramids that have subsequently become known as the Pyramid of the Sun and the Pyramid of the Moon.

Like many other Mesoamerican cities, the street grid is precise and oriented slightly askew from the cardinal directions. There are two different parts to the city, one around the Pyramid of the Sun, which deviates from the cardinal directions by about 15.5 degrees clockwise, and another farther to the south that deviates by about 16.5 degrees. Curiously, quite a large area in between seems to follow one north-south convention but the other an east-west one, resulting in street intersections, and even individual buildings, that have corners of around eighty-nine degrees and ninety-one degrees.

In all likelihood, one or two different sightings fixed the original alignments in each direction and were then propagated as more streets were constructed. But what was being sighted upon? One possibility is that the north-south direction reflects the orientation of the Pyramid of the Sun directly upon the hill Cerro Gordo to the north. Indeed, when viewed from the south, the



The Temple of the Sun at Teotihuacan, Mexico, reflecting the shaping of the hill, Cerro Gordo, to the north. (Courtesy of Clive Ruggles)

pyramid does seem to "reference" the hill behind by mimicking its shape. Others have argued that the focus of interest was topographic features on the eastern horizon. But it may be misleading to consider the Teotihuacan street grid in isolation. Systematic studies of the orientations of the street grids of Mesoamerican cities show that deviations of between fifteen degrees and eighteen degrees clockwise from north-south-east-west are surprisingly common; indeed, they form a distinctive orientation group. This characteristic strongly implies that they were fixed using a common astronomical determinant.

Yet no overwhelmingly convincing possibilities emerge, especially among celestial objects rising to the east. A possible explanation of the east-west direction is that it aligned in the west with the horizon setting position of the Pleiades, but if so it is curious that the orientations of structures spanning many centuries remained on the same orientation, while the setting direction shifted owing to precession. Another possibility is that the direction corresponds to sunset on April 30 and August 13, dates significant because the longer interval between them is exactly 260 days, or the length of the sacred cycle that was a defining feature of all Mesoamerican calendars.

See also:

Horizon Calendars of Central Mexico; Mesoamerican Calendar Round; Mesoamerican Cross-Circle Designs.

The Street of the Dead at Teotihuacan, Mexico, viewed from the Temple of the Moon at its northern end. (Courtesy of Clive Ruggles)

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Theodolite Surveys

The theodolite, sometimes referred to in the United States as a *surveyor's transit,* is the surveying instrument that is most useful in determining the astronomical potential of structural alignments at archaeological sites such as prehistoric monuments. Although the designs of theodolites vary considerably, as they have throughout the century or so that they have been manufactured, their fundamental components remain invariable. These consist of a telescope that can be pointed in any direction, together with two graduated circles, mounted horizontally and vertically, which enable that direction to be defined quantitatively. In order to determine the astronomical potential of (say) a point on the horizon as viewed from a given observing position—in other words, to determine the apparent positions of the distant celestial bodies in relation to that closer feature—the direction of that point from the observer is precisely what we need.

Any direction can be defined in terms of two angles: a horizontal angle measured around from some suitable zero point, and a vertical angle measured up or down from level. Determining the second of these is straightforward. When a theodolite is first set up on its tripod, a leveling process involving various bubbles ensures that the vertical circle is properly zeroed and will give us the required angle, which is known as the *altitude.* The situation regarding the horizontal angle is more complicated. The leveling process ensures that the horizontal circle is truly horizontal, but the zero point on this scale will be pointing in an arbitrary direction. What we actually want is the angle measured clockwise around from true north, which is known as the *azimuth.* However, generally we can't know the direction of true north (at least, to the required accuracy) in advance. What is normally done in practice is to measure what is called the horizontal *plate bearing:* the clockwise angle around from the arbitrary zero point. We must make the adjustment from plate bearings to azimuths in retrospect. This will involve making the same correction to each reading, by adding the actual azimuth of the zero point, sometimes known as *plate bearing zero* or PBZ.

But how do we determine PBZ once we have set up the theodolite? One way is to take a series of timed observations of the sun (it is very important not to look through the telescope when it is pointing at the sun, but the sun's image can be projected on to a piece of paper). The plate bearing of each reading can then be compared with the sun's actual azimuth as determined using published or on-line ephemerides. Each direction we measure (e.g., of a point on the horizon) will eventually be defined in terms of azimuth and altitude, from which we can calculate the *declination* and hence know what rises and sets there, or would have risen and set there at any given era in the past.

A modern theodolite will typically measure the azimuth and altitude of a distant object to a precision of twenty arc seconds or better. For work that does not warrant anything like this sort of accuracy, it may be possible to obtain the necessary information on site using a magnetic compass and a clinometer, or by using large-scale topographic maps or digital topographic data.

In addition to determining the directions of horizon points, etc., it is important to fix the position of the theodolite in space, for example, in relation to a monument. This can be done using a tape, but modern surveying instruments are very useful for this. Theodolites incorporating an electronic distance measurement device (EDM) provide a convenient way of determining the distance between the instrument and a reflector placed within a range of distances appropriate for most site surveys. Total Stations combine this technology with a computer chip that can convert direction-and-distance determinations of measured points into positions in space expressed in a chosen coordinate system. They can also store measurements for downloading directly to a computer, which not only allows the surveyor to dispense with the task of recording measurements manually on site, but also allows for a quick display of the results, using appropriate software.

See also:

Compass and Clinometer Surveys; Field Survey; Precision and Accuracy.
Altitude; Azimuth; Declination.

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Thom, Alexander (1894–1985)

Alexander Thom is widely acknowledged as one of the founding fathers of modern archaeoastronomy. An engineer by profession, he was also a keen amateur astronomer, and he was aware from an early age of the writings of Sir Norman Lockyer on the possible astronomical significance of ancient stone monuments in his native Scotland and elsewhere in the British Isles. His own active interest in the megalithic monuments of Britain, and particularly in his native Scotland, is said to have been aroused in 1933 by the sight, one evening as he was sailing in the Outer Hebrides looking for an anchorage, of one of the stone circles at Callanish silhouetted against the rising moon. Twenty years and many dozens of site surveys later, he began to publish research papers in which he proposed three ideas that, during the 1960s and 1970s, would shake the archaeological world.

The first of Thom's ideas was that stone circles were laid out using a precisely defined unit of measurement, which he called the "megalithic yard." The second, and related, idea was that each circle was laid out according to one of a small number of particular geometrical designs using techniques based upon Pythagorean triangles. The third idea was that a variety of "megalithic sites" incorporated alignments of remarkable precision upon the rising and setting positions of various celestial bodies. Taken together, these showed that "megalithic man," to use Thom's own term, was a competent engineer with considerable technical knowledge, whose accomplishments included sophisticated numeration, geometry, and astronomy—three things that would come to be known together as "megalithic science." Thom's ideas first appeared in book form in 1967, in a slim but highly technical volume called simply *Megalithic Sites in Britain,* which contained the detailed analysis of survey results from over 250 standing stone monuments.

Thom's second book, *Megalithic Lunar Observatories,* published in 1971, set the archaeological world into a turmoil that did not calm down fully until more than a decade later. His claim was that many standing stone monuments were deliberately aligned upon "notches" and other features in distant mountainous horizons, and that these horizon points marked extreme rising and setting points of the moon with incredible precision. To attain that level of precision, prehistoric astronomers would have had to carry out meticulous programs of observation, following them consistently for years if not decades (in other words, over generations). The problem was that these conclusions were completely unpalatable to most prehistorians at the time. Their social models, informed by a variety of archaeological evidence, simply did not fit with such ideas. Yet Thom's results could not easily be refuted: they were based on careful fieldwork and supported by rigorous statistical analysis.

When detailed reappraisals of Thom's ideas on "megalithic astronomy" were eventually completed in the 1980s, it emerged that the supposed astronomical sightlines of very high precision could all be explained away as chance occurrences. On the other hand, certain groups of monuments, such as the recumbent stone circles of eastern Scotland and the short stone rows of western Scotland and southwest Ireland, definitely did contain consistent lunar alignments, though at a much lower degree of precision, that could not be ignored. Similarly, although the idea of a precise "megalithic yardstick" being used all over Britain is not sustainable as Thom conceived of it, the idea that there was a widespread practice of laying out stone circles and other monuments using broadly consistent measurements based upon the human body (such as arm lengths or paces) remains a distinct possibility.

In hindsight, even though Thom's theories have been largely superseded, his work led archaeologists to start thinking about issues and facing problems that they had largely avoided. In particular, Thom's work motivated others to investigate intentional astronomical alignments at prehistoric monuments and eventually resulted in this area of study becoming archaeologically informative and respectable. Finally, Thom pioneered ways of carrying out site surveys using a theodolite, analyzing the data, and presenting the results that are now a fundamental part of field methodology within archaeoastronomy.

See also:

Archaeoastronomy; Field Survey; Lockyer, Sir Norman (1836–1920); "Megalithic Astronomy."

Megalithic Monuments of Britain and Ireland; Recumbent Stone Circles; Short Stone Rows; Stone Circles.

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Thornborough

Situated on a gravel plateau near Thornborough in Yorkshire, northern England, is a remarkable monument consisting of not just one, but an alignment of three large, round Neolithic earthwork enclosures with high outer banks, known as henge monuments. The three henges are almost identical in size and form, each being some two hundred meters across with two entrances on opposite sides, and they are more or less equally spaced some five hundred meters apart, forming an alignment over 1.5 kilometers (1 mile) long. The entrances are oriented along the alignment. Surrounding the henges are a number of other prehistoric features, including two large pits, which appear to have held sizeable wooden posts, aligned upon a double ring-ditch that represents the remains of a ploughed-out barrow.

What makes this monument fascinating from an astronomical point of view is the possibility that it was a pilgrimage center whose astronomical associations tell us not only the time of year when the major ceremonies took place here, but also reveal how people from far afield may have known when to set out in order to arrive in time for those ceremonies.

A number of factors support the pilgrimage center idea. First, the henges were constructed along what is known from other archaeological evidence to have been an important routeway. Second, the formal design of the monuments was evidently important, and it developed over time. The henges are embellishments of earlier, smaller earthwork enclosures, and the central one was built over the central part of an earlier linear earthwork known as a cursus monument, itself over two kilometers (1.5 miles) long. Third, the high outer banks would have obscured the view of the distant skyline (something that is still evident from what remains of the banks today), and this suggests that the henge interiors were exclusive places, cut off from the outside world. Fourth, archaeological field-walking has revealed an almost complete absence of surface scatters of flints from the area immediately around the henges, strongly implying that this was not a place where people routinely lived and worked. Finally, and most extraordinarily, about one kilometer (half a mile) to the east is a large concentration of surface flint, but a good deal of it is non-local and from scattered sources, and lightly worked. It appears that people came here from some distance and brought the stone with them, which implies in turn that this may have been a visitors' encampment, rather than a permanent settlement.

There are a number of locations at the site where prominent features of the monument seem to frame parts of the horizon. Intriguingly, several of these align upon the same asterism, namely the three stars of Orion's belt. It is worryingly easy to identify potential astronomical, and particularly stellar, alignments at almost any site, whether or not they were intentional. But this consistency argues in favor of the Thornborough alignments being deliberate. Viewing along the cursus to the west, the three stars would have been framed by the western terminal as they set. Viewing along the line of the two large timber posts, toward the barrow, an observer would have seen them rising in the alignment. And by the time the bright star Sirius rose, in roughly the same alignment, Orion's belt would have moved up and to the right, to be in line with the henge alignment itself and visible from the henge interiors over their southern entrances. A final, more speculative suggestion is that the three henges themselves formed a representation on the ground of Orion's belt. Because of precession, the rising and setting positions of any star or group of stars varies significantly over a time scale of centuries. Though it is highly inadvisable to try to date sites astronomically by fitting stars to alignments, precession serves at Thornborough to reinforce the Orion's belt alignments, in that the "best fit" dates are wholly compatible with the archaeological estimates of the dates of different features at the monument.

If Thornborough really was a pilgrimage center, then two questions arise. Were there particular times when people congregated here, perhaps for large ceremonies? And if so, and if people had to come from some distance, how did they know when to leave in order to arrive on time?

The astronomical associations of the site may provide answers to both questions. The annual first appearance of Orion's belt in the eastern sky before dawn—its heliacal rise—would have occurred in the late summer. The annual reappearance of Sirius—the brightest star in the sky—would have occurred two or three weeks later. Once Orion's belt had appeared in the predawn sky, it could have provided the necessary reminder for surrounding peoples that a ceremony was imminent. The actual ceremony could then have taken place somewhat later, at the time of the dawn reappearance of Sirius, with Orion's belt now prominently visible above the southern entrance of each henge just before dawn. Such a ceremony would have taken place in early autumn, when the harvests were in and the seasonal workload had eased up for a while.

This interpretation of the Thornborough henges was made possible using a combination of sky visualization software and virtual reality software. It shows the potential of this type of approach in contrast to the more traditional procedure, which is to survey horizon alignments and then calculate declinations.

See also:
Astronomical Dating; Orion; Pilgrimage.
Circles of Earth, Timber, and Stone; Cursus Monuments.
Heliacal Rise; Precession.

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Total Stations

See Theodolite Surveys.

Tri-Radial Cairns

Tri-radial cairns are a distinctive type of Bronze Age monument found on the moorlands of northern England, comprising three radial "arms" of stones, typically no more than two meters (six feet) long and half a meter (two feet) high, extending out from a common center. Modest in size and easily mistaken for sheep shelters or other more modern constructions, their status as prehistoric monuments was only recognized in the 1990s. Over twenty examples are now known, with a major concentration of eight at Lordenshaws in Northumberland.

The state of preservation of the known tri-radial cairns varies. It is often difficult to determine with any great precision the original direction of each of the arms, even assuming that they were straight in the first place. Nonetheless, there is a clear general consistency in the orientations, and this invites an astronomical explanation. In each case one of the arms points approximately due north, always to within about thirty degrees and in the majority of cases to within ten degrees. The remaining two arms point southeastward and southwestward respectively, with a similar scatter in the "best-fit" directions.

A group from the Border Archaeological Society who discovered the cairns has suggested that they might have been constructed by making observations of the sun around the time of the summer solstice. The technique would have been to erect a vertical post and to build the three arms in the direction of the shadow at sunrise, noon (when the shadow is shortest), and sunset. This might not have been done to any great precision, so we might expect a considerable scatter in the resulting orientations even at the time of construction. (It would also require clear skies, but given the tiny change in the sun's motions on days near the solstice, there would be many opportunities to take advantage of suitable weather conditions.) The result would be radial orientations concentrated around azimuths of 0 degrees, 135 degrees, and 225 degrees respectively.

But there is a simpler explanation that fits the data just as well—in fact, better. Suppose that one arm was oriented to the north, either by using the sun's shadow at noon (on any day of the year), or by reference to the diurnal motions of the stars at night, the other two arms being simply placed at regular intervals round the cairn. This would result in radial orientations concentrated around azimuths of 0 degrees, 120 degrees, and 240 degrees. Of course this begs the question of why the chosen number of arms was three, but the explanation could well have nothing to do with astronomy.

There is no conclusive evidence to support either of these explanations, but the fact that they are both viable shows the dangers of fitting particular astronomical orientations too readily, and not considering equally plausible alternatives. It also demonstrates the principle known as *Occam's razor,* which advises us that there is no need to resort to a complex hypothesis to explain some data if a simpler one will explain the data just as well. Here, the "regular spacing" explanation is arguably the simpler one and more consistent with the data.

See also:
Azimuth; Diurnal Motion.

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U

Uaxactún, Group E

See Group E Structures.

Uxmal, Governor's Palace

See Governor's Palace at Uxmal.

V

Venus

See Inferior Planets, Motions of; Venus in Mesoamerica.

Venus in Mesoamerica

The planet Venus is the third brightest regularly visible object in the skies, behind the sun and moon. Its cycle of morning and evening appearances was well known to the ancient Mesoamericans, partly because it seemed to fit naturally with other astronomical cycles, in that five Venus cycles exactly equaled eight year-cycles of 365 days. In fact, five Venus cycles do not quite equal eight years, and we would view the near-coincidence of these two periods merely as an accident of nature. The ancient Mesoamericans, on the other hand, saw it as a significant property of the cosmos and this had two far-reaching consequences. The first was that they, and particularly the Maya, could integrate cycles of Venus with ease into the other intermeshing cycles of their calendar. Direct evidence of the care with which the synodic cycles of Venus were observed by the Maya comes from the Dresden Codex, where the motions of the planet are carefully tabulated and correlated with other astronomical cycles. The heliacal rising of Venus was probably the most significant event to the Maya, and certainly a time of dread for the Aztecs.

The second consequence was that Venus appeared to have a relationship with the seasons, even though a particular seasonal configuration of Venus would only recur after eight years, and so Venus became strongly associated with rain, fertility, and maize. It also appears to have become strongly associated with warfare and ritual sacrifice, with military campaigns carefully timed according to Venus-related prognostications. The two are related, since one of the main purposes of human sacrifice was to petition the gods for rain. There was also a clear association between Venus and the sacred ballgame played throughout Mesoamerica; this is evident from the common occurrence of Venus symbols both in depictions of the game in codices and on the garments and body decoration worn by the players themselves.

See also:

Cacaxtla; Dresden Codex; Caracol at Chichen Itza; Governor's Palace at Uxmal; Kukulcan.

Inferior Planets, Motions of.

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W

Wedge Tombs

Wedge tombs are a distinctive type of megalithic passage tomb found all over Ireland, but mainly in the west. Over five hundred examples are known, and while they vary widely in size, they do have a defining characteristic: a trapezoidal central chamber, its sides formed by two lines of large, upright stones (orthostats), which is wider and higher toward the entrance end, forming a wedge shape. The bulk of wedge tomb construction took place in the second half of the third millennium B.C.E., placing them chronologically toward the end of a rich tradition of Neolithic tomb construction in Ireland.

The other property that confirms the wedge tombs as a useful category of monuments is the strong consistency in their orientations. Nearly all known examples face the western arc of the horizon, with the majority facing southwest. It is unusual to have such a clear preference for westerly orientation among a group of Neolithic tombs, let alone such a substantial one. The only other example in Britain or Ireland is the few dozen Clava cairns of northeast Scotland. The fact that the Clava cairns also seem to represent a late development suggests that a strong predilection for westerly/southwesterly orientations only developed toward the end of the Neolithic. A similar preference is evident in the orientations of the axial stone circles of southwest Ireland, a region where there is a major concentration of wedge tombs, as well as among the recumbent stone circles of northeast Scotland, which occupy an area close to that where the Clava cairns are found.

What is the astronomical significance of the wedge tombs? Viewed in the context of groups of later prehistoric temples and tombs found all over western Europe, their pattern of orientation fits the "sun descending or setting" model. In other words, each tomb was oriented upon a position where the sun was seen either to set, or to be descending in the sky, on a significant day—perhaps the day on which construction was begun. However, there is one well-studied example that provides tantalizing evidence of more particular concerns. This is the tomb of Altar, situated on the south coast of the Mizen peninsula at the very extreme of southwest Ireland, close to the village of An Tuar Mór (Toormore).

The Altar tomb commands a clear view down toward the tip of the Mizen peninsula, and is directly oriented upon the conspicuous Mizen Peak, which forms a distinctive pyramid shape on the horizon some twelve kilometers (eight miles) away. Added to this, the tomb's orientation may have had a calendrical significance. As was first pointed out by Boyle Somerville, who surveyed the monument in 1931, it is oriented upon the position of sunset within a couple of days of February 4 and November 5. These are two of the mid-quarter days, which along with the solstices, equinoxes, and the other two mid-quarter days divide the year into eight equal parts. This interested Somerville because the November date corresponded to the festival of Samhain in the Celtic calendar.

The problems with this interpretation apply to all supposed equinoctial and mid-quarter-day alignments, many of which were highlighted in reassessments of the "megalithic" calendar proposed in Britain by Alexander Thom. On the other hand, an intriguing aspect of Altar is the existence of archaeological evidence that suggests a sequence of ritual activity stretching from around 2000 B.C.E. up to at least the first century C.E. This evidence might support the argument of continuity of tradition into "Celtic" times.

However, Altar does not seem to be typical even of the wedge tombs in its immediate vicinity, at least to judge from an analysis of nine other wedge tombs in the Mizen peninsula. Even the impressive topographic alignment appears to be a "one-off." This means that, as with other single instances among groups such as the solstitially aligned axial stone circle at Drombeg, one must continue to wonder whether the alignments could have arisen fortuitously rather than intentionally.

See also:

Celtic Calendar; Equinoxes; "Megalithic" Calendar; Mid-Quarter Days; Prehistoric Tombs and Temples in Europe; Somerville, Boyle (1864–1936); Thom, Alexander (1894–1985).

Axial Stone Circles; Clava Cairns; Drombeg; Recumbent Stone Circles.

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Worldview

See Cosmology.

X

Xochitecatl

See Cacaxtla.

Y

Years B.C.E. and Years before 0

There is great potential for confusion between the ways that archaeologists and astronomers reckon dates before the birth of Christ. For the archaeologist, the year before C.E. 1 is 1 B.C.E. In other words, there was no "year 0." The convention amongst astronomers, on the other hand, is to count years backward on a linear scale, so that the year before the year 1 was the year 0, the year before that was –1, and so on. This means, for example, that the archaeologist's year 331 B.C.E. is the astronomer's year –330.

This issue becomes crucially important, for example, at the Iron Age causeway site of Fiskerton in England, where it has been proposed that episodes of reconstruction may have been associated with lunar eclipses. In order to test this idea, archaeologically determined tree-ring dates need to be compared with astronomically determined eclipse dates.

See also:
Fiskerton.

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Yekuana Roundhouses

The Yekuana live amid the rainforests of southern Venezuela, along the banks of the river Orinoco and its tributaries. Their traditional dwellings are communal roundhouses large enough to house several families. They have walls of wattle and daub and a huge conical roof, thatched over, through which the central pole protrudes, pointing directly upwards at the heavens.

According to Yekuana myth, the design of the roundhouse was handed down by the Sun (Wanadi) himself, the creator of the world, and reflects the properties of the cosmos in a variety of ways. A circular inner room represents the sea (this is used as sleeping space for bachelor men as well as a place for rituals and ceremonials presided over by the village shaman), and the outer ring, divided radially into compartments where different families live, represents the land. The roof is seen as a reflection of the celestial dome: it is supported by upright posts known as "pillars of the stars," and the horizontal crossbeam supporting it, always placed in a north-south orientation, has the name of the Milky Way. The center post reaches down into the underworld and up, beyond the roof, to the heavens. Placed centrally within the roof space, about three meters (ten feet) above the floor, is a set of tie beams forming a rectangular structure. This has a practical purpose in helping to support the crossbeam and providing a frame from which the men sleeping in the central space can hang their hammocks. However, its precise rectangular shape also has a cosmological significance: the directions of the four corners from the center pole are the directions of sunrise and sunset at the solstices and, together with the pole itself, represent the four corners and center of the world.

A trapezoidal opening in the western or southwestern side of the roof doubles as a vent for smoke and as a source of light. It is closed in the wet season (when the roundhouse fills unpleasantly with smoke), but opened up in the dry season; at this time its orientation, well away from the southerly or southeasterly direction of the prevailing wind, ensures that only rarely will it catch the wind thus blocking the escaping smoke. However, this does not explain why a northerly or northeasterly orientation could not equally well be chosen in many cases. The reason for this may be that the opening originally had a third purpose, as an observation window. The beam of the afternoon sun crosses the interior of the house, its movement marking out the time of day and the time of year. The interior of the house is richly decorated with paintings depicting scenes and figures important in Yekuana myth, some of which are lit up by the beam of sunlight at certain times. There are structural alignments, too: thus on the winter solstice, the sunbeam reaches the northeastern corner of the internal rectangle.

The Yekuana roundhouse was truly a model of the cosmos. It may also, in some senses, have functioned as an observatory, in the sense that observations of sunlight through the roof opening could have been used as a clock or calendar. It may even have been used to observe the night sky. There is no ethnographic evidence to support this claim directly, although the same is known to have been the case among some indigenous North America groups, such as the Pawnee.

The Yekuana creation myth, and a very specific set of principles of construction conceived within the framework of that myth, ensure that the traditional roundhouse not only incorporates sound structural principles and pragmatics for living, but also reflects and reinforces the prevailing worldview. It is interesting to speculate on how much of the cosmological symbolism incorporated just in the overall structure of the roundhouse could have been guessed at by an archaeologist of the future if all historical records had been lost. The answer is probably very little, a sobering thought when we struggle to interpret, for example, roundhouses surviving in Europe from the Iron Age.

See also:

Cosmology; Solstitial Directions.
Iron Age Roundhouses; Navajo Hogan; Pawnee Earth Lodge.
Solstices.

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Z

Zenith Passage of the Sun

If you are within the tropics—but only if you are within the tropics—you will have the opportunity to see the sun pass directly overhead. The highest point in the sky is known as the zenith, so this event is known technically as *solar zenith passage*. Solar zenith passage will happen at local noon on two separate days in the year, but what those days are will depend upon your latitude on the earth. Right on the Tropics themselves, it happens on just one day in the year: the June solstice at the Tropic of Cancer in the northern hemisphere, and the December solstice at the Tropic of Capricorn in the south. A little south of the Tropic of Cancer, the dates of solar zenith passage will be a little before and after the June solstice: the farther south you are, the further apart these dates will be. At the equator, the dates occur exactly six months apart, at the two equinoxes. Moving farther south again, the two dates gradually converge on the December solstice.

One way of visualizing this is to imagine a tightly coiled spring wrapped around the earth with its open ends on the two Tropics, and its 183 coils not quite following lines of latitude. There is always some point on the earth where the sun is currently overhead, and from the June solstice to the December solstice this point will trace slowly along the coils of the spring, going around once every twenty-four hours and moving inexorably southwards along the coils, until the December solstice is reached and the sun starts to move back northwards again.

Times when the sun passes close to the zenith stand out, because people and other upright objects cease to have shadows. Such times have sacred and practical significance in a variety of cultures within the tropics. A number of legends identify it as a time when the way is open into the upper world. In some Guatemalan villages, for example, the two dates of zenith passage coincide with springtime and August rains, and are marked by ritual observances that still live on in Christian tradition in the form of parades. In ancient Hawai‘i, the moment of solar zenith passage was a time with great *mana,* or sacred power. It was a time when a person's shadow was no longer visible and was thought to have retreated directly into the brain through the top of the head; a person's spirit could exit at this time.

The coming of the days when the sun will pass through the zenith may be recognized in various ways, for example, by observing the rising or setting position of the sun on the horizon, or by watching for the heliacal rise or set of certain stars or asterisms. Sometimes we have evidence of devices that marked the actual moment of solar zenith passage, often in a dramatic way. Zenith tubes, which allowed the light of the sun to pass down into a dark place only at the time of zenith passage, are known at the Mesoamerican cities of Monte Alban and Xochicalco.

The zenith sun may hold one of the keys to the mystery of why Necker Island, a remote and uninhabitable rock lying well beyond the larger islands of the Hawaiian chain, is covered in temple platforms. It may have been an especially sacred place because it lay right on the Tropic of Cancer, at the very edge of the region where the sun reaches the zenith.

See also:
Antizenith Passage of the Sun; Equinoxes; Zenith Tubes.
Necker Island.
Heliacal Rise; Solstices.

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Zenith Stars in Polynesia

The paths of the stars across the sky depend upon the observer's latitude. At any given latitude, only certain stars will pass directly overhead. Conversely, any given star will only be seen to pass overhead from one particular latitude on earth. For this to happen, the observer's latitude has to be equal to the "latitude" of the star on the celestial sphere—in other words, its declination.

The New Zealander David Lewis, in his efforts to trace surviving fragments of traditional methods of navigation in the Pacific, encountered a number of references to "the star on top," "the overhead star," "the star that points down upon an island," and the like. Taken together, these suggest the former existence of a Polynesian tradition in which different islands were seen to have distinctive "marker" stars. Most intriguingly, a Tahitian chant recorded in 1818 listed eight "pillars that hold up the heavens." The declinations of several of these stars, Lewis found, corresponded in C.E. 1000 (since they change slightly over the centuries, owing to precession) to the latitudes of various southern Polynesian islands, from the Line Islands in the north down to New Zealand in the south. The implication is that the overhead stars, marker stars, and pillar stars could have been zenith stars for particular islands.

The extent to which zenith stars were used by Pacific navigators is another question. Zenith stars cannot be used to plot a course, merely to determine the current latitude. Even to do the latter at all successfully, one has to identify the upward direction with reasonable accuracy, which is of course difficult on a swaying canoe. On the other hand, Lewis himself did achieve this reasonably satisfactorily by siting up the mast, and there are various documented references to zenith stars being used for navigation, particularly in Micronesia. However, even with zenith star observations as a back-up, Oceanic navigators would still have needed to use other methods (such as a combination of star compasses and dead reckoning) in order to locate distant islands.

See also:
Navigation in Ancient Oceania.
Celestial Sphere; Declination; Precession.

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Zenith Tubes

Most people who lived in the tropics in the past would have been broadly aware of the two times of year when the sun passed more or less directly overhead at noon and they ceased to have shadows. If they wished to determine the precise dates when zenith passage occurred, though, they would have needed to construct an instrument. A vertical, straight-sided post would have sufficed—a gnomon whose shadow would have dwindled to nothing at the appropriate time. So runs a plausible argument; but to reason in this way is to approach the issue from a modern Western perspective. If people had wished instead to harness the sacred power of such a moment, for whatever ideological or political ends, they would surely have created a hierophany. One way to achieve this would have been to construct a long vertical tube opening into a dark chamber below. This would create a breathtaking effect when the light of the zenith sun suddenly passed directly down the tube and, for a few precious moments, brought a sudden transformation to the normally dark space.

Two of the most discussed examples of possible zenith tubes are found in Mesoamerica. One is at the Early Classic site of Monte Alban, a little under four hundred kilometers (250 miles) southeast of Mexico City, close to the modern city of Oaxaca. Monte Alban was the capital city of the Zapotec state, which formed in the valley of Oaxaca around 500 B.C.E. and grew steadily in power and influence until it reached its apex around C.E. 300–600. The massive main plaza, built on a flattened hilltop, was its ceremonial heart. Visitors cannot fail to be impressed by the sheer size of this plaza, which measures more than three hundred meters by two hundred meters (1,000 feet by 650 feet). Nor can they fail to notice something extremely strange about Building J, situated on the central axis towards one end: it is wildly skewed with respect to all the other buildings. Rather than being oriented along the plaza like all the others, it is aligned directly upon Building P, one of several stepped buildings along the eastern side. And halfway up the steep steps of Building P is a curious feature. Here, reached through a narrow entrance, is a small room built directly under the steps, and at the back of it is a bench. Above the bench is a narrow vertical tube about 1.5 meters (five feet) high leading up to an opening higher up the staircase. Some have suggested that this tube could be merely a chimney. But several other features in the alignments at Monte Alban suggest that it could have been an astronomical observing device.

The other Mesoamerican zenith tube, at Xochicalco, is on an altogether different scale from the one at Monte Alban. Located in the state of Morelos, some seventy kilometers (forty-five miles) south of Mexico City and about fifteen kilometers southwest of the city of Cuernavaca, Xochicalco's situation—draped over a series of artificially flattened and terraced hilltops overlooking a deep valley over a hundred meters (330 feet) below—is nothing short of stunning. This city-state flowered early in the Epiclassic period, c. C.E. 700–900 following the collapse of Teotihuacan to the north and Monte Alban to the south. The tube here is over forty centimeters (sixteen inches) wide and descends for more than five meters (sixteen feet) before opening out into the roof in the far corner of a cave chamber almost twenty meters (sixty-five feet) long and twelve meters (forty feet) wide, dug out of the living rock. The chamber is supported by three rock pillars and reached by a network of subterranean passages.

The effect of the midday sun shining down the Xochicalco zenith tube is spectacular indeed, sending a vertical beam of bright sunlight down into the dark cave. But because of the width of the tube, this phenomenon is not confined to the days of solar zenith passage. In fact, the sun first shines di-

Building J at Monte Alban, Mexico, showing its anomalous orientation, as viewed from Building P, upon which it is aligned. (Courtesy of Clive Ruggles)

rectly down the tube, producing a brief spot of sunlight on the chamber floor, at local noon on April 30. As the sun passes closer to the true zenith at noon on successive days, the length of time when its light shines directly onto the floor increases, as does the proportion of its disc that is visible at maximum, until May 15, when it passes directly across the zenith at noon. After this, the length and proportion visible start to decrease again until the solstice is reached, when the noonday sunbeam has almost disappeared. The sequence is then repeated in reverse: zenith passage is reached on July 29, and the last spot of direct sunlight is seen on around August 12. A number of early descriptions dating back to the mid-nineteenth century reassure us that no dubious reconstructions have taken place and that these alignments are reliable.

Since it was first investigated astronomically, there have been many further suggestions about the Xochicalco tube. One is that this is just an approximate zenith device, but others argue that the dates of appearance and reappearance of noon sunlight are significant, since they fall exactly fifty-two days before and after the solstice respectively, and the fifty-two-day interval is calendrically significant. Furthermore, the length of the period of darkness—before the sun starts to appear at noon again—is (within a day or two of) 260 days, exactly the length of the sacred calendar cycle or *tonalpohualli.* Still others suggest that the moon might have been at least as important as the sun at Xochicalco, since at minor standstill it passes directly through the zenith at this latitude. The idea is given some credence by the discovery, in excavations during the 1980s, of a unique crescent-moon-shaped stele.

We cannot be certain that the Monte Alban and Xochicalco zenith tubes were really used for the purposes of astronomical observation, but a good deal of circumstantial evidence supports this view. Furthermore, the existence of solar zenith passage devices like this seems plausible enough in the context of Mesoamerican worldview, in which (with variations) the up-down axis is a fundamental means of orientation, together with the four cardinal directions. The importance of the zenith sun is also well attested in historical accounts, iconography, and ethnography. The effect of sunlight entering the underground chambers is certainly spectacular, and it is hardly surprising that the Xochicalco "observatory" has become a popular tourist attraction. If we are lucky, other examples still wait to be discovered in the future, in Mesoamerica and elsewhere.

See also:

Zenith Passage of the Sun.
Mesoamerican Calendar Round; Teotihuacan Street Grid.
Moon, Motions of.

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Zodiacs

See Ecliptic.

Bibliography

This general bibliography contains the principal sources used in compiling the entries, together with a number of additional works. Some focus upon broad themes and issues in cultural astronomy and typically include a range of case studies; some relate to particular cultures with a greater or lesser emphasis on practices relating to the sky; and some serve to put such astronomy in a broader cultural context. Others provide essential information for those wishing to visit and investigate particular monuments first hand: this category includes serious guides and gazetteers. The list also includes a small number of works that introduce background concepts and information, both from astronomy and from the human sciences. Journal articles are included only where they address broad themes and include material of which summaries cannot readily be obtained in any available book. Likewise, web sites are cited only in exceptional cases, because they do not constitute a permanent medium. A small number of the cited works describe the development of this field of study, or themselves form landmarks within that development. The cited works are in English unless otherwise stated.

The reader should approach the literature on ancient astronomy with caution. Because of its interdisciplinary nature, peppered with popular misconceptions, the subject is particularly prone to sensationalism and uncritical scholarship. These creep all too frequently into academic publications from which they can easily become propagated further in books directed at a wider audience. Collective works and conference proceedings may, likewise, contain articles varying widely in content, approach, and quality. Short notes are included against many of the works listed in the bibliography, in an attempt to help the reader navigate this minefield and to select reliable and authoritative sources, or else to approach the wider available literature with a duly critical eye. Various encyclopedia entries elaborate further on some of the main problems and issues.

Journals and Series

There are a small number of journals devoted to cultural astronomy. The following lists the principal ones. Academic papers on ancient astronomy also regularly appear in a broad variety of academic journals spanning a wide range of disciplines.

Archaeoastronomy, the bulletin, subsequently journal, of the Center for Archaeoastronomy, College Park, MD. Published by the Center for Archaeoastronomy. Vols. 1 (1977)–11 (1993). [Vols. 12–13 (1996) published as *Songs from the Sky* (see Chamberlain et al. 2005 below). Superseded by the University of Texas Press journal, see immediately below.]

Archaeoastronomy: The Journal of Astronomy in Culture. Vols. 14 (1999) to date. Published by the University of Texas Press.

Archaeoastronomy, the supplement to the *Journal for the History of Astronomy.* Nos. 1 (1979)–27 (2002). Published by Science History Publications, Cambridge, England. [Archaeoastronomical articles may also be found in the parent *Journal for the History of Astronomy,* particularly before 1979 and since 2003.]

Astronomie et Sciences Humaines, Nos. 1 (1988)–7 (1991). Published by l'Observatoire Astronomique de Strasbourg. [In French. Superseded by Jaschek 1992 and annual publications from SEAC meetings.]

Culture and Cosmos. Vols. 1 (1997) to date. Published by Culture and Cosmos, Bristol, England. [Includes archaeoastronomy and historical astronomy, but the main emphasis is upon the history of astrology. Vol. 8 (2004) published as *The Inspiration of Astronomical Phenomena* (see Campion 2005 below).]

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Rivista Italiana di Archeoastronomia, Vols. 1 (2003) to date. Published by Edizioni Quasar di Severino Tognon, Rome. [In Italian.]

The "Oxford" series of international symposia on archaeoastronomy are held at intervals of three to five years and are the principal conferences in the field. These have been published as follows (for full details cross-refer to the general bibliography below):

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Mérida, Mexico, 1986 (see Aveni 1989).
St. Andrews, Scotland, 1990 (see Ruggles and Saunders 1993; Ruggles 1993).
Stara Zagora, Bulgaria, 1993 (as yet unpublished).
Santa Fe, New Mexico, USA, 1996 (see Fountain and Sinclair 2005).
La Laguna, Tenerife (Spain), 1999 (see Esteban and Belmonte 2000; a number of keynote papers were published separately in vol. 15 of *Archaeoastronomy: The Journal of Astronomy in Culture*).
Flagstaff, Arizona, USA, 2004 (as yet unpublished).

In Europe, the publications of annual conferences on archaeoastronomy since 1988 have formed a diverse but as yet unbroken series. Since 1993 these have been produced under the auspices of the European Society for Astronomy in Culture (SEAC). For full details cross-refer to the general bibliography that follows.

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Glossary

This glossary gives short definitions of certain terms that occur regularly within thematic entries and case studies. Some readers will find useful a fuller explanation of some of these concepts, and an asterisk indicates that the topic is elaborated further in the main body of the encyclopedia. Italicized words cross-refer to other glossary entries.

*ACCURACY. The closeness of a measurement to the true value. Cf. *Precision.*

*ACRONICAL RISE. [Alternatively spelled "acronychal," for example in British usage.] Strictly, the rising of a star at sunset. This event is not directly visible and the term is sometimes loosely applied to the annual last visible rising of a star in or after the evening twilight.

*ACRONICAL SET. [Alternatively spelled "acronychal," for example in British usage.] Strictly, the setting of a star at sunrise. This event is not directly visible and the term is sometimes loosely applied to the annual first visible setting of a star in or before the morning twilight.

*ALTITUDE. The angle between the direction to an observed point and the horizontal plane through the observer, with a positive value indicating that the point is above the observer. Cf. *Elevation.*

ANTIZENITH. The point directly beneath the observer, also known as the *nadir.* Cf. *Zenith.*

ARC MINUTE. An angle equal to one sixtieth part of a degree, and hence 1 / (60 × 360) or one 21,600th part of the whole circle. This angle is roughly equivalent to the distance between the front and back of a sheep or similar-sized animal viewed side-on (one meter, or three feet) at a distance of about three kilometers (two miles). The apparent diameter of the sun and moon, by comparison, is about thirty arc minutes.

ARC SECOND. An angle of one sixtieth of an *arc minute*, and hence 1 / (60 × 60 × 360) or one 1,296,000th part of the whole circle. This angle is roughly equivalent to the distance between the eyes of a sheep or similar-sized animal viewed front-on (ten centimeters, or four inches) at a distance of about eighteen kilometers (eleven miles).

ASTERISM. In modern astronomy, a grouping or pattern of stars that does not form a (modern Western) constellation; in cultural astronomy the term may also be applied to a (historical or indigenous) constellation.

ASTROLABE. An instrument for measuring and determining the positions of the sun and bright stars as seen from given locations at given times; in many senses a precursor to the modern planisphere.

*AZIMUTH. Bearing clockwise from due north.

CELESTIAL NORTH POLE. Point on the *celestial sphere,* visible from any location in the northern hemisphere where the relevant part of the sky is unobscured, around which the celestial bodies appear to rotate daily (in a counterclockwise direction).

CELESTIAL SOUTH POLE. Point on the *celestial sphere,* visible from any location in the southern hemisphere where the relevant part of the sky is unobscured, around which the celestial bodies appear to rotate daily (in a clockwise direction).

*CELESTIAL SPHERE. Imaginary sphere surrounding the observer on which the celestial bodies can be considered to be positioned.

*CIRCUMPOLAR STAR. For a given location on earth, a star that is always above the horizon and so never sets or rises.

CODEX. In the Mesoamerican context, an indigenous "book" made from pages of painted tree bark folded together in concertina fashion.

CODICES. Plural of *Codex.*

COSMOGRAM. A symbolic representation of the cosmos, as found in some Mesoamerican *codices.*

CULMINATION. The moment when a celestial object reaches its highest *altitude,* which happens when it crosses the *meridian.*

*DECLINATION. "*Latitude*" on the spinning *celestial sphere.*

*DIURNAL MOTION. Daily rotation of the *celestial sphere.*

DOLMEN. Most usually, a *megalithic monument* comprising a large horizontal stone supported by a number of upright stones. Sometimes the term is applied to a wider range of megalithic tombs.

*ECLIPTIC. The annual path of the sun through the stars on the *celestrial sphere.*

*ELEVATION. Height above sea level. Cf. *Altitude.*

*EQUINOXES. Technically, the times when the sun's *declination* is zero, but often loosely taken to mean the halfway point in time between the *solstices.*

*EXTINCTION. The dimming of a star at low *altitude* due to the earth's atmosphere.

GNOMON. A rod, pole, or equivalent device whose function is to cast a shadow for the purposes of reckoning time, typically as part of a sundial.

*HELIACAL RISE. The annual first appearance of a star, or the first appearance of a planet, in the eastern sky before sunrise after a period of invisibility.

*HELIACAL SET. The annual last appearance of a star, or the last appearance of a planet, in the western sky after sunset before a period of invisibility.

HENGE. A prehistoric enclosure consisting of a circular ditch and adjacent external bank, of which many were constructed in Britain and Ireland during the Late Neolithic period. Associated rings of timber posts or stone circles were common but not universal, and were not always part of the original design. Although the term "henge" derives from Stonehenge (that is, like Stonehenge but without the stones), Stonehenge itself—ironically—is not now generally considered a henge, since the circular ditch and bank at the site are of early (Middle Neolithic) date and the bank is internal to the ditch.

HIEROPHANY. An appearance of the sacred, or the experience of this. The term is commonly used to describe a spectacular effect perceived as mystical, such as those produced by sunlight and shadow at ancient sites, but only on rare occasions.

INFERIOR PLANET. A planet whose orbit is closer to the sun than the Earth's. The two inferior planets, Venus and Mercury, are both visible to the naked eye, although Mercury, being closer to the sun, is more seldom seen. Cf. *Inner planet* and *Superior planet.*

INNER PLANET. One of the four planets closest to the sun, namely Mercury, Venus, Earth and Mars. Cf. *Inferior planet* and *Outer planet.*

KIVA. A subterranean building in the southwestern United States, roofed and used as a meeting place or for sacred ceremonies.

LATITUDE. Angular distance from the equator of a location on the earth. Because of a confusion of terminology it is better to speak of *declination* on the spinning *celestial sphere.*

LUNATION. The time that it takes the moon to complete its cycle of phases. Equivalent to *synodic month.*

MAJOR STANDSTILL LIMITS. The most northerly or southerly possible rising or setting positions of the moon, which can only be reached around the time of a "major standstill," which only occurs every 18.6 years. See the encyclopedia entry Moon, Motions of.

MEGALITHIC MONUMENT. Any monument built of large stones, applied particularly to prehistoric tombs and temples built in Europe during the Neolithic and Early Bronze Age.

*MERIDIAN. Imaginary line across the sky, joining the north point on the horizon to the south point and passing through the *zenith.*

MIDSUMMER SUNRISE. Popular term for sunrise at the *summer solstice.*

MIDSUMMER SUNSET. Popular term for sunset at the *summer solstice.*

MIDWINTER SUNRISE. Popular term for sunrise at the *winter solstice.*

MIDWINTER SUNSET. Popular term for sunset at the *winter solstice.*

NADIR. The point directly beneath the observer, also known as the *antizenith.* Cf. *Zenith.*

NEOLITHIC. Broadly speaking, a prehistoric society whose subsistence is based on animal herding or agriculture but lacks any knowledge of metallurgy. Meaning "New Stone Age," the term is a remnant of the "three-age" classification (Stone Age, Bronze Age, Iron Age) that has long been superseded as a primary indicator of social development but is often still retained for convenience. The term is seldom used in reference to the Americas.

*OBLIQUITY OF THE ECLIPTIC. The amount by which the earth's axis is "tilted" with respect to the plane of its orbit about the sun. More precisely, the angle between the earth's axis and the direction perpendicular to the plane of its orbit.

OUTER PLANET. One of the five planets furthest from the sun, namely Jupiter, Saturn, Uranus, Neptune and Pluto. Only Jupiter and Saturn are visible to the naked eye. Cf. *Inner planet* and *Superior planet.*

*PARALLAX. The difference between the position of an object in the sky as viewed (conceptually) from the center of the earth and (actually) from somewhere on the earth's surface. It is only significant in the case of the moon.

*PRECESSION. Short for "precession of the equinoxes." A gradual change in the orientation of the earth's axis with respect to distant space, which results in the positions where the solstices and equinoxes occur slowly shifting along the earth's orbit. This significantly alters the position of any given star in the sky over a timescale of centuries.

*PRECISION. The degree of consistency of several measurements of the same thing by a particular method. Cf. *Accuracy.*

QUADRANT. An instrument for measuring the *altitude* of a celestial body.

QUADRIPARTITE COSMOLOGY. A perception of the world, or cosmos, as viewed from a central place as being divided horizontally into four quarters, each with distinctive properties and qualities.

*REFRACTION. The bending of light, in particular as it passes through the atmosphere, which causes astronomical objects near to the horizon to appear higher than they actually are.

SARSEN. A type of large sandstone block found extensively in southern England and used in the construction of Stonehenge.

*SOLSTICES. The times of year when the sun reaches its highest or lowest *declination* and moves on its most extreme daily path across the sky (which, outside the tropics, is its highest or lowest). One solstice occurs on or close to June 21 and the other on or close to December 22.

SUMMER SOLSTICE. June *solstice* (northern hemisphere) or December *solstice* (southern hemisphere).

SUPERIOR PLANET. A planet whose orbit is farther out from the sun than the earth's. The superior planets visible to the naked eye are Mars, Jupiter, and Saturn. Cf. *Inferior planet* and *Outer planet.*

SYNODIC MONTH. The time that it takes the moon to complete its cycle of phases. Equivalent to *lunation.*

TRILITHON. A formation of three stones, with two vertical uprights holding up a horizontal lintel, as at Stonehenge and Ha'amonga-a-Maui.

TROPICAL YEAR. The seasonal year, equal to the time taken by the sun to complete one circuit around the *celestial sphere*. It is not quite the same as the time taken for the earth to complete an orbit of the sun (the "sidereal year") because of *precession*.

WINTER SOLSTICE. December *solstice* (northern hemisphere) or June *solstice* (southern hemisphere).

ZENITH. The point in the sky directly above the observer. Cf. *Antizenith* or *nadir.*

ZODIAC. A set of *asterisms* spread around the *ecliptic* and hence useful as reference points for the sun's annual motion through the stars. The term is commonly used to refer to the particular set of twelve zodiacal constellations that has come to be recognized in the modern Western world.

Topic Index

This list indicates the different types of entries to be found in this encyclopedia. CONCEPTS *includes broad definitions and explanations of* KEY CONCEPTS, *together with nontechnical explanations of more* BASIC CONCEPTS, *mostly astronomical, often elaborating on short definitions to be found in the glossary. Some entries elaborate upon key* THEMES *and* ISSUES *relating to ancient astronomy.* CASE STUDIES, *which illustrate these and other key issues and themes, are organized in this list by continent: the Americas are split into North, South, and Mesoamerica, and Europe is divided into Britain and Ireland and Continental Europe. The entries also include a very small sample of* PEOPLE *important in the development of our knowledge of ancient astronomy, and an equally small sample of* SKY OBJECTS AND EVENTS AND THEIR CULTURAL SIGNIFICANCE. *Items such as Sirius and the Pleiades that do not receive entries of their own may nonetheless appear in others, and these can be located using the general index. Finally, there are brief descriptions of a number of* PROCEDURES AND TECHNIQUES *that are used in the modern practice of archaeoastronomy.*

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This index lists the various case studies according to the modern country within which the culture area in question falls. Where they span more than one, only the main one (or ones) is listed. Entries not confined to a single country or even a few countries are listed separately at the end.

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- Stonehenge
- Thornborough
- Tri-Radial Cairns

Scotland

- Ballochroy
- Brainport Bay
- Brodgar, Ring of
- Callanish
- Circles of Earth, Timber, and Stone
- Clava Cairns
- Iron-Age Roundhouses
- Kintraw
- Maes Howe
- Megalithic Monuments of Britain and Ireland
- Recumbent Stone Circles
- Short Stone Rows
- Stone Circles

United States of America

Mainland

- Cahokia
- Casa Rinconada
- Chaco Canyon
- Chaco Meridian
- Chaco Supernova Pictograph
- Fajada Butte Sun Dagger
- Hopewell Mounds
- Hopi Calendar and Worldview
- Lakota Sacred Geography
- Medicine Wheels
- Navajo Cosmology
- Navajo Hogan
- Navajo Star Ceilings
- Pawnee Cosmology
- Pawnee Earth Lodge
- Pawnee Star Chart

Hawaiian Islands

- Hawaiian Calendar
- Kumukahi
- Kumulipo
- Nā Pali Chant
- Necker Island

Venezuela

- Yekuana Roundhouses

Wide Geographical Extent

The following broad case studies are not confined to a single country or even a few countries, and in some cases not even to a single continent:

- Church Orientations
- Gregorian Calendar
- Islamic Astronomy
- Mithraism
- Navigation in Ancient Oceania
- Polynesian and Micronesian Astronomy
- Polynesian Temple Platforms and Enclosures
- Prehistoric Tombs and Temples in Europe
- Roman Astronomy and Astrology
- Sky Bears
- Star Compasses of the Pacific
- Zenith Stars in Polynesia

Chronological Index

This list provides a broad indication of the date range, or the principal data range, within which particular case studies fall. The ranges chosen are unavoidably arbitrary, and in such a very wide variety of examples the accuracy to which a date can be quoted varies considerably, both because of the inherent nature of the example concerned and the different types of dating evidence available in any given case. As a general rule we can only present a best estimate on the basis of current evidence. Some items span more than one date range, and the "Modern indigenous" category includes several examples where cultural traditions demonstrably extend back well into the past. Entries not confined to a single date range or even a few such ranges are listed separately at the end.

Labels such as Palaeolithic, Neolithic, Copper/Bronze/Iron Age, *etc. have been avoided here on the grounds that they reflect developments occurring at (sometimes very) different dates in different parts of the world and place undue emphasis upon purely technological innovation. Readers interested in the correlation between astronomical practice and the nature of the human society concerned are referred to the Cultural Index that follows.*

c. 30,000 B.C.E.

Abri Blanchard Bone

Fourth millennium B.C.E.

Antas
Boyne Valley Tombs
Cursus Monuments
Megalithic Monuments of Britain and Ireland
Nabta Playa
Newgrange
Prehistoric Tombs and Temples in Europe
Thornborough

Third millennium B.C.E.

Ancient Egyptian Calendars
Antas
Avebury
Babylonian Astronomy and Astrology
Beltany
Brodgar, Ring of
Callanish
Carahunge
Circles of Earth, Timber, and Stone
Coffin Lids
Crucuno
Cumbrian Stone Circles
Egyptian Temples and Tombs
Grand Menhir Brisé
Maes Howe
Megalithic Monuments of Britain and Ireland
Prehistoric Tombs and Temples in Europe
Pyramids of Giza
Recumbent Stone Circles
Rujm el-Hiri
Stone Circles
Stonehenge
Thornborough
Wedge Tombs

Second millennium B.C.E.

Ancient Egyptian Calendars
Axial Stone Circles
Babylonian Astronomy and Astrology
Ballochroy

Brainport Bay
Bush Barrow Gold Lozenge
Circles of Earth, Timber, and Stone
Clava Cairns
Coffin Lids
Drombeg
Egyptian Temples and Tombs
Is Paras
Kintraw
Megalithic Monuments of Britain and Ireland
Minoan Temples and Tombs
Nebra Disc
Nuraghi
Prehistoric Tombs and Temples in Europe
Short Stone Rows
Son Mas
Stone Circles
Swedish Rock Art
Taulas
Tri-Radial Cairns

First millennium B.C.E.
General
Ancient Egyptian Calendars
Babylonian Astronomy and Astrology
Chinese Astronomy
Delphic Oracle
Fiskerton
Hesiod (Eighth Century B.C.E.)
Hopewell Mounds
Horizon Calendars of Central Mexico
Iron Age Roundhouses
Mesoamerican Calendar Round
Prehistoric Tombs and Temples in Europe
Taulas
Temple Alignments in Ancient Greece
Venus in Mesoamerica

Second and first centuries B.C.E.
Julian Calendar
Roman Astronomy and Astrology
Sarmizegetusa Regia
Star of Bethlehem

First millennium C.E.
General
Chinese Astronomy
Easter Island
Group E Structures
Hawaiian Calendar
Hopewell Mounds
Javanese Calendar
Land of the Rising Sun
Maya Long Count
Mesoamerican Calendar Round
Mesoamerican Cross-Circle Designs
Nasca Lines and Figures
Navigation in Ancient Oceania
Necker Island
Polynesian and Micronesian Astronomy
Polynesian Temple Platforms and Enclosures
Saroeak
Teotihuacan Street Grid
Venus in Mesoamerica
Zenith Stars in Polynesia
Zenith Tubes

First to fourth centuries C.E.
Crucifixion of Christ
Mithraism
Pantheon
Roman Astronomy and Astrology

Seventh to tenth centuries C.E.
Angkor
Cacaxtla
Caracol at Chichen Itza
Governor's Palace at Uxmal
Kukulcan

Second millennium C.E.
General
Chinese Astronomy
Church Orientations

Islamic Astronomy
Island of the Sun
Kumukahi
Land of the Rising Sun
Medicine Wheels
Nā Pali Chant
Navigation in Ancient Oceania
Polynesian and Micronesian Astronomy
Polynesian Temple Platforms and Enclosures
Saroeak
Star Compasses of the Pacific
Zenith Stars in Polynesia

Eleventh to fourteenth centuries C.E.

Angkor
Cahokia
Caracol at Chichen Itza
Casa Rinconada
Chaco Canyon
Chaco Meridian
Chaco Supernova Pictograph
Dresden Codex
Fajada Butte Sun Dagger
Ha'amonga-a-Maui
Kukulcan
Maya Long Count
Mesoamerican Calendar Round
Venus in Mesoamerica

Fifteenth and sixteenth centuries C.E.

Aztec Sacred Geography
Ceque System
Cusco Sun Pillars
Gregorian Calendar
Mesoamerican Calendar Round
Quipu
Venus in Mesoamerica

Seventeenth century onward

Gregorian Calendar
Kumulipo
Navajo Star Ceilings
Pawnee Star Chart

Modern indigenous

Aboriginal Astronomy
Andean Mountain Shrines
Barasana "Caterpillar Jaguar" Constellation
Borana Calendar
Emu in the Sky
Hopi Calendar and Worldview
Inuit Cosmology
Lakota Sacred Geography
Mangareva
Misminay
Mursi Calendar
Navajo Cosmology
Navajo Hogan
Pawnee Cosmology
Pawnee Earth Lodge
Yekuana Roundhouses

Unknown or Wide Chronological Span

The following items are undated within wide bounds or cover an extremely wide chronological range:

Namoratung'a
Presa de la Mula
Sky Bears

Cultural Index

In this list, case study entries are classified according to the type of society concerned. Such categorizations inevitably oversimplify, in that they ignore and obscure many important variations between one human society and another. In the 1960s and 1970s, many archaeologists believed that one could classify human societies in straightforward terms—the main ones being band, tribe, chiefdom, and state—arguing a strong correlation between the size of the political unit, social and economic organization, and means of subsistence. Such naïve ideas have largely been superseded. One problem is that they carry the implication that we can measure every human society's progress along a single inevitable path of social development. Added to this, in the case of past societies, the very categorization is a matter of interpretation from the available archaeological or historical evidence and (particularly in prehistory) can in itself be highly questionable. The extent to which (for example) communities in Neolithic Britain developed from segmentary societies (i.e., with no social group or village dominating over the others) into chiefdoms has been a matter of intense debate, and even to focus on this question is arguably to be distracted from more interesting and more complex issues of settlement organization and the development of social differentiation.

For these reasons, the set of categories used in this list is intended merely to give the broadest indication of the nature of the human society responsible for a particular set of practices relating to the sky. Thus the pastoral/agricultural *category covers, on the one hand, communities that are primarily mobile pastoralists and herders, and on the other, societies whose principal means of subsistence is agriculture and who live in fixed homesteads, whether scattered through the landscape or clustered together into villages; the common feature is that they are not organized into chiefdoms or larger political units. It is a broad category but not easy to subdivide, since there is no clear demarcation between mobile pastoralism and sedentary agriculturalism. Likewise the "state" category spans a range from small, competing city-states (as, for example, in pre-Hispanic Mesoamerica) to large empires.*

Hunter-Gatherer
- Aboriginal Astronomy
- Abri Blanchard Bone
- Barasana "Caterpillar Jaguar" Constellation
- Emu in the Sky
- Inuit Cosmology
- Presa de la Mula

Pastoral/Agricultural

Prehistoric
- Antas
- Avebury
- Axial Stone Circles
- Ballochroy
- Beltany
- Boyne Valley Tombs
- Brainport Bay
- Brodgar, Ring of
- Callanish
- Carahunge
- Circles of Earth, Timber, and Stone
- Clava Cairns
- Crucuno
- Cumbrian Stone Circles
- Cursus Monuments
- Drombeg
- Grand Menhir Brisé

Is Paras
Kintraw
Maes Howe
Megalithic Monuments of Britain and Ireland
Nabta Playa
Namoratung'a
Newgrange
Nuraghi
Prehistoric Tombs and Temples in Europe
Recumbent Stone Circles
Short Stone Rows
Son Mas
Stone Circles
Stonehenge
Swedish Rock Art
Taulas
Thornborough
Tri-Radial Cairns
Wedge Tombs

Native American
Andean Mountain Shrines
Hopewell Mounds
Hopi Calendar and Worldview
Horizon Calendars of Central Mexico
Lakota Sacred Geography
Medicine Wheels
Misminay
Navajo Cosmology
Navajo Hogan
Navajo Star Ceilings
Pawnee Cosmology
Pawnee Earth Lodge
Pawnee Star Chart
Yekuana Roundhouses

Oceanic
Easter Island
Mangareva
Navigation in Ancient Oceania
Necker Island
Polynesian and Micronesian Astronomy
Polynesian Temple Platforms and Enclosures
Star Compasses of the Pacific
Zenith Stars in Polynesia

Other
Borana Calendar
Javanese Calendar
Mursi Calendar
Saroeak

Chiefdom
Prehistoric
Brodgar, Ring of*
Bush Barrow Gold Lozenge
Circles of Earth, Timber, and Stone*
Fiskerton
Iron Age Roundhouses
Maes Howe*
Megalithic Monuments of Britain and Ireland*
Nebra Disc
Prehistoric Tombs and Temples in Europe*
Rujm el-Hiri
Sarmizegetusa Regia
Stone Circles*
Stonehenge*

Native American
Cahokia
Casa Rinconada
Chaco Canyon
Chaco Meridian
Chaco Supernova Pictograph
Fajada Butte Sun Dagger
Hopewell Mounds
Nasca Lines and Figures

Polynesian
Ha'amonga-a-Maui
Hawaiian Calendar
Kumukahi
Kumulipo
Nā Pali Chant

Polynesian and Micronesian Astronomy*
Polynesian Temple Platforms and Enclosures*

**Indicates entries that span societies of which only some are generally supposed to be chiefdoms, or where the* chiefdom *categorization is particularly debatable. They are also included under* pastoral/agricultural.

State

Near and Far Eastern Civilizations

Ancient Egyptian Calendars
Angkor
Babylonian Astronomy and Astrology
Chinese Astronomy
Coffin Lids
Egyptian Temples and Tombs
Land of the Rising Sun
Pyramids of Giza

Classical Civilizations (Greece and Rome)

Crucifixion of Christ
Delphic Oracle
Hesiod (Eighth Century B.C.E.)
Julian Calendar
Minoan Temples and Tombs
Mithraism
Pantheon
Roman Astronomy and Astrology
Star of Bethlehem
Temple Alignments in Ancient Greece

Mesomerican City-States

Aztec Sacred Geography
Cacaxtla
Caracol at Chichen Itza
Dresden Codex
Governor's Palace at Uxmal
Group E Structures
Kukulcan
Maya Long Count
Mesoamerican Calendar Round
Mesoamerican Cross-Circle Designs
Teotihuacan Street Grid
Venus in Mesoamerica
Zenith Tubes

Inca State

Ceque System
Cusco Sun Pillars
Island of the Sun
Quipu

Wide Cultural Extent

The following items cover a wide range of human societies:

Church Orientations
Gregorian Calendar
Islamic Astronomy
Sky Bears

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